



## **Regulatory options and alternative governance structures towards less toxic antifouling practices**

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# Changing leisure boat antifouling practices in the Baltic Sea

Results from the BONUS CHANGE project

Edited by Helena Strand, Cecilia Solér, Mia Dahlström







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## Introduction

This publication is an outcome of the BONUS CHANGE project '*Changing antifouling practices for leisure boats in the Baltic Sea*'. Based on working papers, deliverables and articles produced in the project, the publication presents a popular scientific summary and synthesis of the research and results.

The BONUS CHANGE consortium was formed to deliver scientific results that can help to improve policy performance and policy instruments aimed to reduce the spread of hazardous (toxic) biocides from antifouling paints used on leisure boats in the Baltic Sea. In the BONUS call 2012 *Viable ecosystems*, the key theme chosen by the BONUS CHANGE consortium was therefore theme 4.1 – *Governance structures, policy performance and policy instruments*. Moreover, the following sub-themes were addressed 1.4 – *Multilevel impacts of hazardous substances*, and 2.2 – *Meeting the multifaceted challenges in linking the Baltic Sea with its coast and catchment*.

With funding from the BONUS programme ([www.bonusportal.org](http://www.bonusportal.org)), interdisciplinary research has been undertaken during 2014-2017 with the overall objective to reduce the supply of toxic compounds from antifouling paints used on leisure boats in the Baltic Sea. This is suggested to be achieved by changing antifouling practices into sustainable consumption of antifouling products and techniques for leisure boats.

The project has combined research in natural science, business administration and environmental law in order to understand how consumers' behaviours, the market and the legal framework shape the environmental policy performance in the field of toxins from the use of antifouling paints. Through this approach, the BONUS CHANGE project has been dedicated to produce solid and integrated research that can be used to support a change of boaters' practices. The research has relied on four major tasks, organised into different work packages (WP):

- Map consumer practices related to antifouling products and techniques to obtain a behavioural change perspective (WP 2)
- Map the legal framework and the influence of the market on consumers' choice of antifouling techniques for leisure boats (WP 3)
- Thoroughly evaluate performance and environmental impact of antifouling products and techniques (WP 4)
- Participatory and communication-based approach building on strong stakeholder collaboration (WP 5)

The BONUS CHANGE project has received funding from BONUS (Art 185), funded jointly by the EU and the Swedish Environmental Protection Agency, the Academy of Finland, the Innovation Fund Denmark and Projektträger Jülich (PtJ), Germany.



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## Overview – a reader's guide

The first part of this publication sets the overall setting of antifouling in the Baltic Sea and the first chapter (1) provides a short introduction to the context of the project, the Baltic Sea and leisure boat antifouling practices. It thereafter describes how sustainable consumption can be conceptualized and promoted from a system perspective, presenting our system model and the analytical approach of the BONUS CHANGE project.

The next chapter (2) describes fouling and antifouling practices from a historical perspective. Chapter three (3) reports on the current status and situation in the Baltic Sea and the effects of long-term and continued consumption of biocide containing antifouling products. The chapter presents research and findings from empirical field tests around the Baltic Sea; the problem of continued spread of organotin (OTCs) including tributyltin (TBT) compounds from old paint layers, soil and sediment contamination in boatyards and marinas, as well as assessment of environmental impacts on marine organisms in marinas.

The publication thereafter addresses the question of how we can understand current antifouling practices but also promote reduction of antifouling toxins, by changing products, infrastructure and unsustainable consumption behaviour. This is described in separate chapters where chapter four (4) addresses how products and infrastructure can be changed in order to minimize the spread of toxic compounds from antifouling paints. The chapter presents findings from field tests using panels to study the natural fouling pressure and evaluate performance of low vs. high copper containing antifouling paints throughout the Baltic Sea region. Also findings from evaluation of biocide-free methods are presented in this chapter. Chapter five (5) explores several aspects related to antifouling and how we can understand current antifouling practices. This includes how use and maintenance of leisure boats results in different environmental impact but also how antifouling cultures, marina infrastructure and markets, advertising and supply influences antifouling practices. Chapter six (6) concerns the regulatory framework related to antifouling paints and practices, it identifies and discusses different regulatory options which can be taken with the aim to minimise the use of toxic paints. This is followed by chapter seven (7) that explores how different eco-labelling options could help achieving the objective of the BONUS CHANGE project. The last chapter (8) summarizes and discuss possible solutions to reduce the excessive toxicity in the marine environment resulting from leisure boat antifouling paint practices.

## Chapter 1

### Constructing sustainable consumption from a system perspective – the case of leisure boat antifouling use in the Baltic Sea

Cecilia Solér, Mia Dahlström, Ann-Kristin Eriksson Wiklund, Lena Gipperth, Diane M. Martin and Helena Strand

The Baltic Sea is a highly sensitive and interdependent brackish-water ecosystem that gives rise to a unique flora and fauna. But it is also under severe stress. The use of biocide-based antifouling paints on leisure boats is one of the stressors, causing high toxicity and risk to the Baltic Sea ecosystems. This first chapter provides an introduction to the context of the BONUS CHANGE project; the Baltic Sea and leisure boat antifouling use. It also describes how sustainable consumption can be promoted from a system perspective.

#### The Baltic Sea – a unique and particular sensitive sea area

The Baltic Sea is a world unique brackish water body and the youngest of the World's Seas – formed some 10,000-15,000 years ago after the last Ice Age. In fact, the Baltic Sea is one of the planet's largest brackish waters, governed by special hydrographical and climatic conditions. It is composed of high salinity seawater from the North East Atlantic and fresh water from rivers and streams draining from an area four times larger than the Baltic Sea itself.

The Baltic Sea hosts species of various origins and environmental tolerances. These immigrated to the sea some 10,000 to 15,000 years ago or have been introduced to the area during the relatively recent history of the system. The Baltic Sea has only one known endemic species, a brown algae named *Fucus radicans* (Wennerström et al., 2013). Salinities in the Baltic Sea varies from the south to the north spanning from some 20 PSU (Practical Salinity Unit) in the south where high salinity water from the northeast Atlantic enters the sea through the Kattegat and the Sound and the Belts, to about 2 PSU in the Bothnian Sea in the north of the Baltic Sea. In general, but not in all organism groups, high salinity is associated with higher species richness. In comparison with fully marine areas, the Baltic Sea supports fewer species (Ojavear et al., 2010). Furthermore, the Baltic ecosystem is still evolving since it reached its current form and salinity level only 2000 years ago. A system made up of so few species is not very stable, and is especially vulnerable to pressures such as fishing, habitat destruction and pollution.

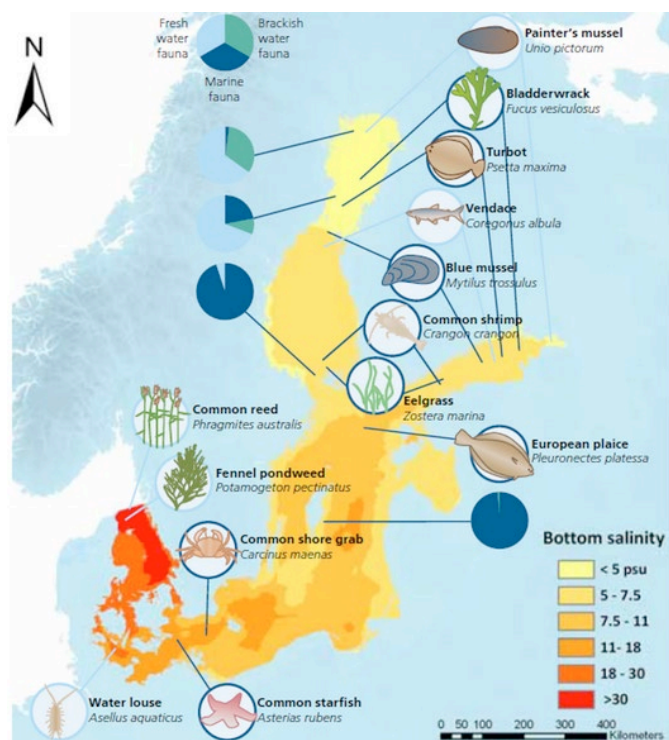


Figure 1.1. The Baltic Sea (HELCOM, 2010).



On average, the water—and all the contaminants discharged from the catchment area with 85 million people from nine countries—remains in the Baltic for decades (HELCOM, 2010). The input of freshwater from the catchment area is larger than the in-flow of saline water from the North Sea. This causes strong stratification of the water column which at times leads to lack of oxygen (hypoxia or anoxia) at the sea floor.<sup>1</sup> Nevertheless, the occasional in-flows of saline water bring well-oxygenated water, which breathes life into the deeper parts of the Baltic Sea.

Due to the special hydrographical, biological and climatic conditions, the Baltic Sea is vulnerable. Marginal ecosystems such as the Baltic Sea can be of great conservation value because they may harbour unique genetic variation and even novel species. At the same time, the dense human population of the Baltic drainage area imposes threats to its aquatic biota via eutrophication, habitat destruction and overfishing (Ducrotoy & Elliott, 2008).

Over the past 100 years, the natural environment of the Baltic Sea has degraded dramatically. Decades of human activities in and around the Baltic Sea continue to negatively impact its sensitive environment and impacts can be observed over the entire sea area. Today, the Baltic Sea is one of the most used and polluted seas in the world with one of the most threatened marine ecosystems (HELCOM, 2010). One of the key threats to the well-being of the Baltic Sea ecosystem is the waterborne transport and discharges as well as airborne emissions of excessive amounts of nutrients and hazardous substances. The greatest source of nutrients causing eutrophication, as well as hazardous substances comes from land-based human activities (HELCOM, 2010).

This has resulted in a number of measures and initiatives to help protect the Baltic Sea. The HELCOM (Helsinki Convention and Helsinki Commission) has worked for over 40 years to improve the environmental status of the Baltic Sea through regional cooperation between EU Member States in the Baltic Sea area. In 2007, the HELCOM adopted the Baltic Sea Action Plan, which visions and goals include that hazardous substances should be reduced to near natural levels (HELCOM PSBA, 2007).

Moreover, the Baltic Sea is classified as a Particular Sensitive Sea Area under the International Maritime Organization (IMO). A Particularly Sensitive Sea Area (PSSA) is an area that needs special protection through action by IMO because of its significance for recognized ecological, socio-economic or scientific reasons and which may be vulnerable to damage by international maritime activities (IMO).

## Marine biofouling – a concern for boaters in the Baltic Sea

The coastal ecosystems are especially important for the well-being of the Baltic Sea because they function as spawning, nursery and feeding grounds for a wide range of marine organisms including invertebrates and commercial fish species. Marine environments and coastal areas are also important for human recreation and outdoor activities. Leisure boating is a popular recreational activity; about 3.5 million leisure boats are active in the Baltic Sea's coastal areas (Baltic LINes, 2016). A great majority of the boats used in the Baltic Sea are coated with antifouling paints that contain toxic

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<sup>1</sup> Water stratification implies that water masses with different properties (such as salinity) form different layers, this can act as barrier to mixing of the water and could lead to lack of oxygen e.g. close to the sea bed.

compounds and are designed to prevent fouling organisms to attach to the boat hull. Unfortunately, the use of these paints also causes critical ecological problems in the vulnerable ecosystem.

Marine biofouling is the settlement, accumulation and subsequent growth of a wide range of fouling organisms. The fouling consists of slime (formed by microorganisms) and algae as well as invertebrates such as barnacles and mussels (Wahl, 1989). Biofouling accumulates on all surfaces in the marine environments, including both natural and man-made surfaces such as boat hulls. Among the biofouling organisms, the barnacle is considered to be the most serious fouler as it is persistent, sturdy and difficult to remove from boat hulls.



**Figure 1.2** Fouling on a surface left unprotected in the sea for 3 years in row, from the North Sea in 2017. Photo: Kjell Saebbo

As said, boat owners typically combat marine fouling by painting the hull with antifouling paints containing biocides. These paints contain toxic heavy metals such as copper and zinc and are designed to erode, slowly leaching biocidal heavy metals into the marine environment, keeping the barnacles and other fouling organisms from adhering to the boat hull. Biocides also spread to the sea during maintenance work when the hull is washed, scraped or sanded. Through these practices, old paint flakes are removed and washed into marine environment or spread by airborne dust.

The continuous use of the antifouling paints adds to the spreading of harmful biocides in the coastal ecosystem (Dahlström et al., 2014; Srinivasan & Swain, 2007) and increases the load of hazardous substances in sediments and soils, especially in harbour areas and boatyards where the majority of the maintenance work is performed (Eklund & Eklund, 2014). Hence, the use of toxic antifouling paints can be considered one of the highest environmental risks to the well-being of coastal ecosystems in the Baltic Sea.

### Sustainable consumption alternatives: Biocide-free antifouling methods

There are alternatives offering environmentally friendly and sustainable methods to deter biofouling on leisure boat hulls. One category includes different types of biocide-free paints. The other category includes mechanical methods that can be applied to remove or prevent organisms to settle (Table 1.3). The biocide-free antifouling methods are described more in detail in Chapter 4.

**Table 1.3.** *Biocide-free antifouling methods.*<sup>2</sup>

| Biocide-free paints  | Other biocide-free antifouling methods  |
|--|---|
| <ul style="list-style-type: none"><li>• Non-eroding paints including fibre coatings and non-stick coatings where the latter implies paints with very low adhesion force to the fouling organisms, i.e. silicon polymers (elastomers) or Teflon-like coatings. Used in combination with cleaning.</li></ul> | <ul style="list-style-type: none"><li>• Mechanical methods: boat washers and under-water brushing in combination with no paint or “easy to clean”, hard and non-abrasive coatings. Land storage/lifting devices, which can be used in combination with hand or high-pressure washing. Hull covers mounted at the site of berth, minimize boat hull water contact during periods when the boat is moored.</li><li>• Electrical/sound systems: ultrasound or electric currents.</li></ul> |

Mechanical methods can be combined with information systems to increase their efficiency. For example, field panel monitoring of fouling development combined with SMS-alarms can be used to inform when an intense settlement of barnacle larvae is likely to occur in the area so that boat owners can wash their boat hulls at the optimum time to prevent barnacle colonization. This information service is available in several sites along the Swedish east coast (Skärgårdsstiftelsen, 2017). In the BONUS CHANGE project, tests have also been made where boat owners themselves monitor the barnacle settlement by deploying Plexi glass panels close to their boat (see Chapter 4).

Despite available information on the negative impact of toxic antifouling paints on marine life and personal health, it is still the most widely used method among leisure boat owners in the Baltic Sea. The BONUS CHANGE project was therefore designed produce research results underpinning proposals for ways for actors involved in antifouling products to become more environmentally friendly and suggest sustainable solutions to combat marine biofouling.

## Antifouling as a case of (un-)sustainable consumption and the rational for taking a practice-related approach

Sustainable consumption efforts aim to reduce negative environmental and social problems caused by human consumption. Its implementation is highly connected to sustainable development, which cannot be separated from the way that societies produce and consume.

Antifouling is an illustrative example of unsustainable consumption practices<sup>3</sup> that persists, in spite of availability of more environmentally friendly alternatives on the market. The practices are also maintained despite scientific evidence showing how the spread of toxic compounds from antifouling paints threatens the well-being of ecosystems and the near-coastal waters of the Baltic Sea (CEPE, 2003). The critical question is how consumption can be shifted toward more sustainable practices.

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<sup>2</sup>Categorization based on Watermann et al., 2004.

<sup>3</sup>Consumption is a concept that includes meanings of market exchange and demand. Apart from a strict purchase-definition, it can also mean how products and items are used (Warde, 2005) and is sometimes conceptualized as a process (rather than an act) because it involves activities of search, use and disposal of any good or service (Kilbourne et al., 1997). For our case, antifouling consumption entails purchase, use and maintenance practices of antifouling products, methods and techniques.



To be able to answer that question, we first have to understand what drives boat owners' consumption practices. Researchers suggest that consumer behaviour may be governed in three ways.

The first is the idea that consumers are rational decision makers (Moisander, 2000; Shove, 2010). They choose products according to the benefits they provide and the problems that need to be solved. For example, a person will buy environmentally friendly products if s/he believes that this is better for the environment or that it can bring personal benefits, e.g. it is a healthier product. This means that sustainable consumption can be promoted by educating and encouraging consumers to buy sustainable products and services e.g. by providing them with environmental-related information.

Yet, people don't always follow rationale choice pathways. Research have for example found that even if consumers are provided with information in order to encourage them to purchase environmentally friendlier products, a majority of the consumers, including those who are environmentally concerned, shows limitation to take-in and act upon that information (Leire & Thidell, 2005). Instead, consumers can choose a product based on a feeling or because a trusted friend or family member uses the same product. In the case of antifouling, there is a long tradition of Baltic Sea boat maintenance and many boat owners learned how to care for their boats from their parents and grandparents. Even those who are environmentally concerned and might have a belief that sustainable consumption is better for themselves, their children and the environment, don't always choose the most sustainable option. This phenomenon is called the attitude-behaviour gap (Young & Middlemiss, 2012; Kollmuss & Agyeman, 2002), the knowledge-to-action gap (Markkula & Moisander, 2012) or the value-action gap (Shove, 2010; Young et al., 2010). Moreover, it indicates that a prerequisite for change in consumption choices is not only residing with the individual consumer, nor is it solely information or environmental concerns that consumers incorporate into their decision-making process.

A second line of researchers therefore suggest that consumption is culturally and socially embedded and influenced by structures, norms and forces that goes beyond the control of individuals (Budon, 2006). Consumers find meaning and identify themselves in their purchasing, following the dominant cultural and social norms (Connolly & Prothero, 2008; Markkula & Moisander, 2012). Consumption thereby also becomes embedded or locked into institutional, societal and cultural structures. The branding and advertising of products and services influence norms that shape the consumption (Caruana & Crane 2008; Zwick et al., 2008). For the case of antifouling practice for leisure boats, consumption of products and application of antifouling techniques becomes related to the antifouling methods, products and services that are available on the market. Important is also the advertisement and branding of a boating lifestyle that includes actors such as firms, wholesale sector and retailers.

The BONUS CHANGE project has focused on a third perspective, a middle-way between the rational choice and cultural imperative models. The perspective implies that consumption is a daily practice best understood by actually focusing on the practices, i.e. how consumption is done, the context where it takes place, the individual competences and know-how, society's structures and norms but also material objects which can steer the practices (Mylan et al., 2016; Geels et al., 2015). This means that we have examined how antifouling and maintenance is done.

In other words, in order to understand consumer behaviour, the focus has been on the doings and the practices of boat owners (Röpke, 2009; Shove et al., 2005; Warde et al., 2005).

The approach also provides information for how sustainable consumption patterns can be promoted, as transitions into new ways of doing antifouling and boat maintenance. These new ways take into consideration how boat owners work with both paints and mechanical antifouling options. They consider the role of marina management, availability of mechanical and physical antifouling methods such as boat washers and other equipment. They consider how rules and regulations encourage boat owners to comply with more sustainable antifouling and maintenance practices. We can see that it also makes the picture a bit more complex, since promotion of sustainable consumption need efforts from a number of different actors.

### Antifouling consumption from a system perspective: Constructing a system model

Based on this, it becomes relevant to look beyond choices made by end consumers and instead shift focus to boat owner practices, shaped by structures and cultures in marinas and boat clubs as well as in antifouling markets.

To approach antifouling consumption, we suggest a model where attention is paid not only on leisure boat owners as consumers but rather to understand the complexity and reality they are facing in their everyday boating practices.

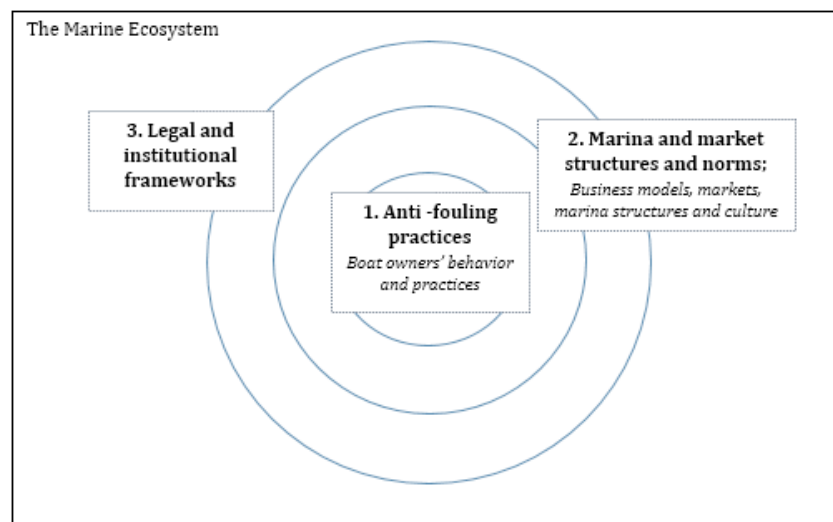
We therefore have to examine the context of the Baltic marine ecosystem, legislations and norms that influence boating cultures, boaters' behaviour and practices. We also have to explore structures and cultures related to markets and businesses (marinas, products, infrastructure etc.) that can either support or hinder sustainable consumption of antifouling products and services. These all interact and shape antifouling practice in different parts of the Baltic Sea region.

The figure below illustrates the system model (Figure 1.4), which includes the following components:

- 1) Antifouling practices: boat owners' behaviour and boating practices. This relates to the type of antifouling techniques and methods used by the boat owners in order to keep the hull clean and free from fouling. Important is also how maintenance work of the boat hull is performed, especially at the start and the end of the boating season.
- 2) Marina and market structures and norms: The cultural meaning of "the good sailor" is one who cares for the boat by keeping biofouling to a minimum, thereby limiting frictional drag and hampered manoeuvring and as a result reduces the need to motor which leads to excessive fuel use and greenhouse gas emissions. Boat owners are for example aware that motoring is not the most sustainable practice. Yet even "good sailors" are unaware of that their hull scraping without a tarp or other device to catch bits of old paint and application of higher than necessary toxic paints, negatively affect the marine life. Boat maintenance practices are learned from elders in one's family and from seasoned sailors at boatyards and marinas. But the antifouling practices are also situated and formed by the surrounding structures. This is why marinas are important. Boaters get

access to the sea through membership in a boat club or a marina. The boat clubs and marinas are engaging in certain boating practices (e.g. through provision of infrastructure and regulations). These so-called boat cultures impact boaters' understanding of antifouling practice as part of the boating lifestyle. The role of material infrastructures for sustainable antifouling deserves attention as it may either constrain or enable particular practices (Mylan et al., 2016). Market structures, such as supply and branding of antifouling products influence norms and consumption. Consumers and firms are embedded in social structures such as routines, conventions, rules and habits, as well as in politico-economic structures.

- 3) Legal and institutional frameworks: Last but not least, consumption and practices interact with the overall legal frameworks. There are a number of different regulations within the area relevant for antifouling, from the international and European level to the very local, targeting different aspects of antifouling consumption. This can include technical specifications on chemicals or environmental regulations, as well as rules where to moor leisure boats. The legal framework is important for all actors, including consumers, marinas, paint manufactures, local authorities and national agencies. Rules and regulations have norm-setting effects (e.g. what is accepted antifouling practice or not) which influence both marina cultures and the kind of consumption behaviour boaters' engage in, especially when supervised and enforced (e.g. by sanctions). Moreover, regulations can set the framework for what type of infrastructure that marinas have to provide and this can promote sustainable antifouling practices among boaters. However, different legal rules can interact in different ways and more important is also to explore the context in which rules are applied (or not applied), i.e. legal rules must be studied in their cultural context and are dependent of moral norms and paradigms (Tuori, 2002).



**Figure 1.4.** Sustainable consumption from a system perspective – the case of leisure boat antifouling in the Baltic Sea.

A system approach as referred to here should not be confused with other system analyses directed to the environmental or material flows of products and services, such as in life-cycle assessments (LCA) or input/output analyses. Instead, this system-model connects the regulatory practices and legal sanctions, boater antifouling practice, marina structures, leisure boat cultures and representation of dominant antifouling practice.



Moreover, revealing the multi-levelness of consumption, the model implies a shift away from bottom-up models (consumers acting on free markets) and analyses focusing on top-down (command-control) steering dynamics. Instead, it enables for combining and paying attention to the interactive structures e.g. as this allows for both higher level of analysis (e.g. regulatory frameworks) but also the interplay to the micro level (e.g. acts or perception of individuals).

This is also linked to the purpose of the BONUS CHANGE project, i.e. to gain understanding of how the linkages between individual behaviour, market actors and the legal framework shape the environmental policy performance in the field of toxin spread to the marine environment from the use of antifouling paints.

The system model is here applied to the case of antifouling consumption in the Baltic Sea, although we consider it to be of general relevance for studying other types of consumption systems as well and serve as a model also for other industries, contexts and communities.

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## Chapter 2

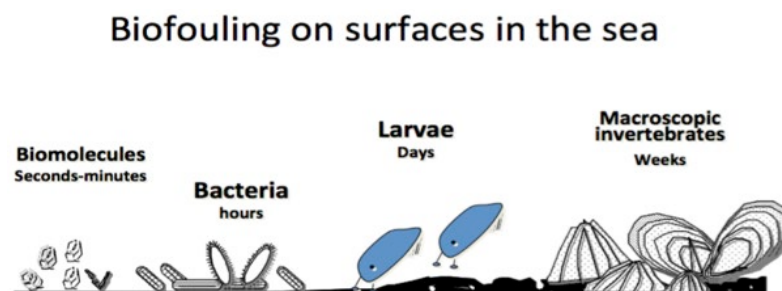
### Biofouling and antifouling – why should we care?

Mia Dahlström, Britta Eklund, Ann-Kristin Eriksson Wiklund, Maria Lagerström and Anna-Lisa Wrangé

“FOR God’s sake and our country’s,” wrote an 18th-century captain in Britain’s navy to the Admiralty in Whitehall, “send copper bottomed ships to relieve the foul and crippled ones.” Copper coating, first used widely in the 1780s, kept fouling at bay by inhibiting the growth of barnacles, mussels, tubeworms and shipworms (The Economist, 2016).

The distress of the 18-th century captain is evident. Biofouling, that is the growth of marine sessile organisms on manmade surfaces such as boat hulls, is an ancient problem for seafarers, and a current concern for any boat owner. Biofouling decreases vessel speed and affects vessel manoeuvrability with severe consequences for ship safety. It increases the friction, resistance and weight of the boat, leading to increased fuel consumption (Yebra et al., 2004) and emissions of greenhouse gases. It also affects the overall ship maintenance with huge increases in costs for ship owners as a consequence. It is estimated that the costs for the US Navy vessel fleet for moderate biofouling is 180-260 million US dollars annually (Schultz et al., 2011). And the US Navy vessel fleet only makes up about 1% of the global maritime fleet.

Why do these organisms settle on boat hulls and manmade constructions? Because for marine organisms that live their lives attached to surfaces, space is a limiting factor. There are massive amounts of free-swimming larvae and spores that are ready to settle at any time but there is generally a limitation of available hard surfaces to live on in the sea. Finding a free spot that is not too dark, not too light, not too deep, not too shallow and with enough access to food for growth and reproduction is all about competition between different species of marine sessile organisms. Therefore, every new surface that is submerged in the sea is instantly colonized by various microscopic organisms (including e.g. bacteria and microalgae) followed by macroscopic species such as barnacles and mussels. Some organisms like the bay barnacle *Balanus (Amphibalanus) improvisus*, found in temperate waters and in brackish waters such as the Baltic Sea, have specialized on settling on smooth surfaces such as boat hulls. So while boaters enjoy the marine environment and take pleasure in the boating experience offering scenes of bird wildlife, fishing, beautiful and ample forms of sea shells at the beaches and kelps along the rocky shores – there is full activity below the water surface where marine organisms are attaching to boat hulls. These species have been termed foulers.



**Figure 2.1.** The development of a fouling community on a clean hard surface that is in the sea. Within minutes the surface is colonised by bacteria and microalgae, followed by other larvae that settle and form communities of e.g. barnacles, mussels and bryozoans. Illustration: Kent Berntsson



## Different types of fouling on boats

Marine organisms can be divided into “soft” and “hard” foulers. Hard fouling includes organisms with hard calcareous or siliceous shells or structures, such as barnacles, tubeworms, mussels and bryozoans. The fouling communities they generate are generally considered more problematic for leisure boats, compared to soft fouling, which more easily detach from surfaces when the boat makes speed through water or when the boater performs maintenance work on the hull. Soft fouling is typically slime layers consisting of bacteria, diatoms, fungi, protozoa, and filamentous algae, but also tunicates, hydroids and anemones. In the Baltic Sea, the most problematic fouling species is the hard calcareous barnacle *Balanus* (*Amphibalanus*) *improvisus*.



**Figure 2.2.** Examples of fouling organisms that occur on boat hulls, including barnacles, mussels and bryozoans (=“hard fouling”), and filamentous algae, hydroids and tunicates (=“soft fouling”).<sup>4</sup>

## Biology and physiology of fouling organisms

Although the terms fouling and biofouling denote something that is often unwanted, many species that attach to docks, pilings, and boat hulls are also found in natural areas, such as along rocky shores, and play an important role in the health of the environment. They are filter feeders that help clean particulates from the water improving water clarity. They provide nursery habitat for larval fish and crabs, and they are an important source of food for many species including humans. In addition, foulers are really magnificent and beautiful creatures that have evolved shapes, behaviours and solutions that mankind may only dream of.

<sup>4</sup>Montage with photos from Fredrik Pleijel, Burkard Watermann and Anna-Lisa Wrangé.



**Figure 2.3.** The barnacle, *Amphibalanus improvisus*. Photo: Fredrik Pleijel.

What do we mean? Well, the barnacle (Figure 2.3) for example has developed a super strong glue that allows them to remain attached to their home, the underlying surface, for the remainder of their lifetime. This glue is made up of proteins that can cure under water, a feature that researchers and product developers drool over – a biological glue that cures under water would for example mean that operational wounds would not need to be stitched together – they could be glued together!

What more is, the barnacle is both male and female at the same time and has a super long penis – a giant organ that can stretch up to eight times a barnacle's own body length, making it proportionately the biggest penis in the animal kingdom. This allows them to reproduce with various neighbours close to their attachment spot. After fertilization they breed their eggs and release numerous larvae, so called naupliar larvae, which go through several stages before it hatches into the final larval stage – the cyprid larva (Figure 2.4).



**Figure 2.4.** The Cyprid larva. Photo: Kent Berntsson.

This larva, the cyprid, is specialized in finding a spot to settle and metamorphose. It doesn't need to feed since it survives from storage lipids and proteins. It has one sole task – to find a home. Cyprids are transported by near-shore currents and finally land on available surfaces where they explore the underlying substrate, using their highly specialized antennae. This underwater walk is enabled by the secretion of a temporary adhesive made up of proteins (Crisp & Meadows, 1962; Berntsson et al., 2000; Lagerson et al., 2002). Since the home surface is so important, the small larva has a brain and a nervous system that coordinates the signals from the outer world. These signals can be chemical, like pheromones from relatives of the same species that has already colonized the surface (Head et al., 2004; Prendergast et al., 2008) and/or physical signals like the prevailing hydrodynamic regime (Mullineaux & Butman, 1992) or the surface texture (Berntsson et al., 2000). Once the decision is made by the larvae to permanently settle at a surface, this decision is irreversible. The subsequent metamorphosis into a juvenile barnacle takes no longer than 24 hours. In comparison, with butterfly pupas the process of metamorphosis spans from two weeks up to two years. The brain of the larvae, which was once used to explore and make decisions about its surrounding world, is regenerated after settlement. Thus, the adult barnacle has no brain.

Besides the barnacle, there are many other interesting groups of fouling organisms that you can come across in the Baltic Sea and Kattegat region. Here follows a short overview describing these groups.

**Bryozoans** (also known as moss animals) is a common group of foulers that look like crusts or hard patches when attached to a boat hull (Figure 2.2). They come in a variety of shapes and patterns. They are colony-forming animals where many millions of individuals can form one colony. The colonies members are tiny (~0.2mm) zooids, which secrete lime or chitin to build hard little compartments that they live in. Although most individuals in a colony are closely related clones, they can have many different functions in the colony. Some individuals gather food by filter feeding for the colony, whereas others are devoted to protecting the colony or cleaning it.

**Hydroids** are small colony-forming animals that live attached to hard surfaces where they trap food with small tentacles. They are related to corals and jellyfish and similar to these animals, hydroids have stinging cells that they use to catch food. Plant like in appearance, hydroids live in colonies and are often found on the flat bottom of vessels where they are often mistaken for algae. Due to the low light levels on flat bottom areas of a boat, however, it is a safe assumption that filamentous growth on the flat bottom of a leisure boat is likely to be a type of hydroid and not algae.

**Mussels and oysters** are animals with hard, paired shells that sometimes are found as fouling on leisure boats, especially when the boat has not been in use for a while. Mussels attach to surfaces using strong byssus threads that they secrete. Although strong, adhesion to submerged structures by these threads is relatively weak and this tends to limit settlement to stationary structures rather than on active vessels e.g. harbour pillars or jetties. However, some oyster species can attach their calcareous shells directly to a submerged surface, causing problems also for boat owners.

**Tubeworms** are easily recognisable since they live inside calcareous tubes, which protect their soft bodies. They are filter feeders meaning that they catch food by filtering out particles from the water. Tubeworm larvae can recognise their own species resulting in large colonies being established. They tend to settle on stationary structures or on vessels, which spend relatively long time in port. Animal fouling does not require light to grow and can proliferate on any area of an underwater hull, including the flat bottom.

**Filamentous algae** mainly form fouling along the water line of a boat, since they are dependent on light to be able to grow. When there is plenty of light and nutrients and warm temperature in the water, they can grow fast and form thread like fouling. However, this type of soft fouling is relatively easy to remove from the boat using gentle brushing or hosing.

Together, these different fouling groups can form a complex ecosystem on unprotected new hard surfaces in the sea. The fouling process starts within minutes after the substrate has been submerged, where macromolecules like carbohydrates and proteins adhere to the surface forming a basis for the following succession of settling microalgae and bacteria that will be present at the surface within hours. Within days, larvae of macroscopic invertebrates like barnacles, ascidians, tunicates and blue mussels will have colonized the surface. Within one-two weeks, a full biofouling community will be present at the surface. The generalized process here described of the development of a fouling community is of course depending on the availability of larvae in the water column, temperature and sea area, but these are the steps that essentially are involved in forming biofouling.



## Traditional antifouling methods

The 18th century British captain was not the first in history to be distressed by the effects of fouling on his ship. For example, ancient Egyptians used copper plates to stop their canoes from being overgrown by fouling organisms. The problem became even more profound when countries started sailing the seas to find new continents and when worldwide trade and shipping developed in the 17th century.

The first actual patent on an antifouling technique was filed in 1654 with ingredients such as copper, arsenic and gunpowder. In the centuries that followed, several toxic heavy metals, like lead, copper and even mercury, continued to be the solution for seafarers to keep fouling off their hulls.

## The use of TBT and other OTCs in antifouling paints – its rise and fall

By the 1960s, well-known biocides such as tributyltin (TBT) and triphenyltin (TPHT), which belong to the group of organotin compounds (OTCs), revolutionized the market of antifouling products. For a long time, OTCs were the most popular antifouling ingredient in antifouling paints.

OTCs were first synthesized around 1850 (Blunden & Evans, 1990). It would however take nearly 100 years before they were introduced in products. They were first used in the plastic industry as stabilizers in polyvinyl chloride (PVC) (Rosenberg, 2005) while the biocidal properties<sup>5</sup> of certain OTCs were discovered in the 1950's (Champ & Seligman, 1996; Hoch, 2001). The OTCs replaced the current biocides in antifouling paints, mainly copper (I) oxide (Cu<sub>2</sub>O) but also other toxicants such as dichlorodiphenyltrichloroethane (DDT), organomercury and arsenic (Bennett, 1996; Omae, 2003).

By their introduction in the 1960's, the OTC paints would rapidly come to take over the antifouling market because of their efficiency to prevent marine biofouling (Dafforn et al., 2011) and they have been termed the most effective antifouling agents discovered. Although they first were introduced to the recreational yacht market, the commercial shipping market was soon to follow (Bennett, 1996). The OTCs were eventually used on some 70% of the world's shipping fleet (Kiil et al., 2002).

And of course they were popular – they were relatively inexpensive and when used in antifouling paints, the service life of the paint was extended and ships were able to continue sea operations for an extended time period, delaying costly ship repairs. Due to their properties, the OTCs were considered to be the “perfect biocides” as they were toxic at very low concentrations and thought to degrade rapidly in the aquatic environment into harmless inorganic tin (Sn) (Champ & Seligman, 1996; Omae, 2003). As the compounds also are colourless, it was possible to include them in paints formulated in an array of bright colours, something that was, and still is, highly favoured by leisure boat owners (Anderson, 2000).

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<sup>5</sup>A biocide, according to European legislation, has been defined as a chemical substance (or microorganism) intended to destroy, deter, render harmless, or exert a controlling effect on any harmful organism by chemical or biological means. Thus, biocidal products are used to protect humans, animals, materials or articles against harmful organisms like pests or bacteria, by the action of the active substances contained in the biocidal product (Regulation 528/2012/EU).



However, serious environmental concerns arouse around the effects of the OTCs on non-target organisms such as oysters and snails. The first adverse environmental effects related to the use of OTC in antifouling paints were reported from Arcachon Bay in France. Oyster farming was until mid-1970s an important activity in the bay but by the end of the decade, the production was reduced to a 1/5 as the oyster shells got severely thickened and lost considerably in flesh. The collapse of the oyster farming was found to be linked to TBT (Alzieu et al., 1986; Alzieu, 2000). Moreover, imposex (females developing male genitals) was observed in marine invertebrate species in the 1970's. It was firstly reported in a predatory snail (gastropod), a species with no commercial value (Bryan et al., 1986), but later on, imposex was also observed in other species. Evidence of the toxicity of TBT and TPhT was thereafter reported from studies all over Europe followed by similar results from the rest of the world. Consequently, TBT and TPhT were identified as hormone disruptors, causing imposex in molluscs at very low concentrations (nanograms per litre or even lower concentrations) (Gibbs & Bryan, 1996; Horiguchi et al., 2001).

Moreover, it was found that the organotins were highly persistent in the marine environment with a very slow turnover rate. For example, OTCs such as TBT and TPhT are not long-lived in seawater with half-lives of days or weeks (Radke et al., 2008), but they are easily attached (adsorbed) to particles. As these particles sink to the seabed, the OTCs end up in the bottom sediment where their degradation is slower (especially when there is a lack of oxygen, anoxic conditions) where they can persist as toxic OTCs for decades (de Carvalho Oliveira & Santelli, 2010; Batley, 1996). Hence, sediments at the seabed are the primary sink for OTCs. From the sediment, the OTCs can also regularly spread into the seawater and marine environment during resuspension, occurring when sediment settled to the bottom is redistributed through the water by waves caused by e.g. wind or boats (Harris et al., 1996).

Another alarming feature of organotin compounds is that they accumulate in the food chain, in both marine invertebrates and fishes (Fent, 2006). This causes serious adverse effects on marine mammals and other predators.

The increased knowledge of the immense toxicity of the OTCs led to a series of legal actions. Some thirty years after their introduction as antifouling biocides, i.e., in 1989, organotin paints were banned on boats smaller than 25 meters such as leisure boats in the EU (Directive 89/677/EEC). In the International Maritime Organisation (IMO), an international convention was adopted in 2001, which prohibits the use of harmful OTCs in antifouling paints used on ships. The convention was to enter into force 12 months after 25 states representing 25% of the world's merchant shipping tonnage had ratified it (IMO, 2002). This was achieved in September 2007, and consequently, the convention came into force in September 2008. Today (as of September 2017), 76 countries have ratified the convention, representing 93,7 % of the world tonnage (IMO, 2017a; IMO, 2017b).

A ban on ships was also incorporated into EU legislation in 2003, stating that ships sailing the flag of a Member State no longer are allowed to use antifouling systems where organotin compounds act as biocides. As of 1 January 2008, it is required that any present organotin paint layers on EU ships and other ships visiting EU ports either should be removed or that the ships and boats "bear a coating that forms a barrier to such compounds leaching from the underlying non-compliant antifouling system" (Regulation (EC) No 782/2003).

The use of OTCs has also been addressed through environmental quality regulations. In 2000, TBT was classified as a priority hazardous substance in the EU Water Framework Directive, adopted by the European Commission (Directive 2000/60/EC). Less attention has however been awarded to TPhT, both on national and EU level. As an example, there are today no guideline values for soil, sediment or water for TPhT or its degradation products DPhT and MPhT in Sweden.

## Antifouling today

Since the ban of OTCs in antifouling paints, today's marine antifouling paints include other heavy metal additives such as copper and zinc. A typical biocide-based paint erodes slowly over time, giving rise to a slow but controlled release of biocides in the water.

Copper has traditionally been used as a biocide in antifouling paints but it is also a well-known toxicant that is harmful to most organisms, including humans. Studies have found that copper interfere with olfactory sense organs in crustaceans and fish, even at very low concentrations and give rise to sub-lethal effects (Baldwin et al., 2003; McIntyre et al., 2012; Beyers et al., 2001). Because copper may seriously affect behaviours in a range of organisms (including homing behaviour and mating search), it is an unacceptable ecological risk for the Baltic Sea ecosystem. Still in the 21st century, we are using toxic heavy metals to avoid fouling on our ships, no matter how small or large the boat is.

Problems arising from past antifouling practices, as well as the environmental implications of the present use of biocidal antifouling paints will be discussed in next-coming chapter.

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## Chapter 3

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### Soil and sediment contamination at boatyards and marinas and environmental impact on marine organisms

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A majority of the boats in the Baltic Sea are coated with paints containing biocides to prevent fouling organisms to attach and grow on the boat hull. The biocides are not only affecting the fouling organism they are aimed to target. When the boat is in contact with water, it also leaches biocides and chemicals to the surrounding marine environment. Moreover, these substances spread through hull maintenance work that can lead to contamination of the sediment and soil in marinas and boatyards. Heavily toxic biocides such as tributyltin (TBT) have been prohibited to use in antifouling paints, but the paints used today include heavy metals such as copper, a well-known toxicant harmful to most organisms, also for humans (Baldwin et al., 2003; McIntyre et al., 2012; Beyers et al., 2001).

This chapter describes several aspects of the environmental impact caused by the use of biocidal antifouling paints. First, we approach the problem of old paint layers that contains toxic substances and whether organotin compounds (OTCs) such as TBT can still be detected from old paint layers on boat hulls. This is followed by results from another study measuring the current status and situation of soil and sediment contamination in boatyards and marinas. Finally, we provide findings from studies focusing on how biocides used in antifouling paints impact marine organisms living in marinas.

#### Emission of TBT from old paint layers – a lingering problem

Ever since the regulation and ban of OTCs in antifouling paints also stating that any present organotin paint layers either should be removed or sealed (Regulation (EC) No 782/2003), no follow-up inspections have been carried out to ensure that these requirements have been fully implemented or complied with. Findings from several recent studies strongly indicate that OTCs are still emitted from leisure boats. These include:

- Fresh inputs of TBT to surface sediments have been reported in Sweden (Eklund et al., 2008; Eklund et al., 2010; Eklund et al., 2012), in France (Briant et al., 2013) and the southern Baltic Sea (Filipkowska et al., 2013).
- Elevated concentrations of TBT have been found in the sediments of collection basins underneath boat brushers (Eklund et al., 2008).
- High concentrations of TBT have been detected in the water and sludge from wash pads in Sweden and Finland (Ytreberg, 2012; Haaksi & Gustafsson, 2016).

The highest concentrations of OTCs are found in the sediments near the slipway where the boats are taken up and washed by high-pressure hosing (Eklund et al., 2008). Moreover, the concentrations on land where boat maintenance takes place is roughly ten times higher than in the sediment elsewhere (Eklund et al., 2014). These facts strongly indicate that OTCs such as TBT from antifouling paints are still discharged. So where does the TBT come from? Are boat owners using prohibited TBT containing antifouling paints? This is highly unlikely since these paints are not sold in Europe and therefore difficult to get a hold of. A more likely explanation is that the TBT found in the sediment

and in the soil originates from TBT in old paint layers that may be scraped off during hull maintenance work. Given this, BONUS CHANGE research has analysed whether OTCs can still be detected in old paint layers on boat hulls.

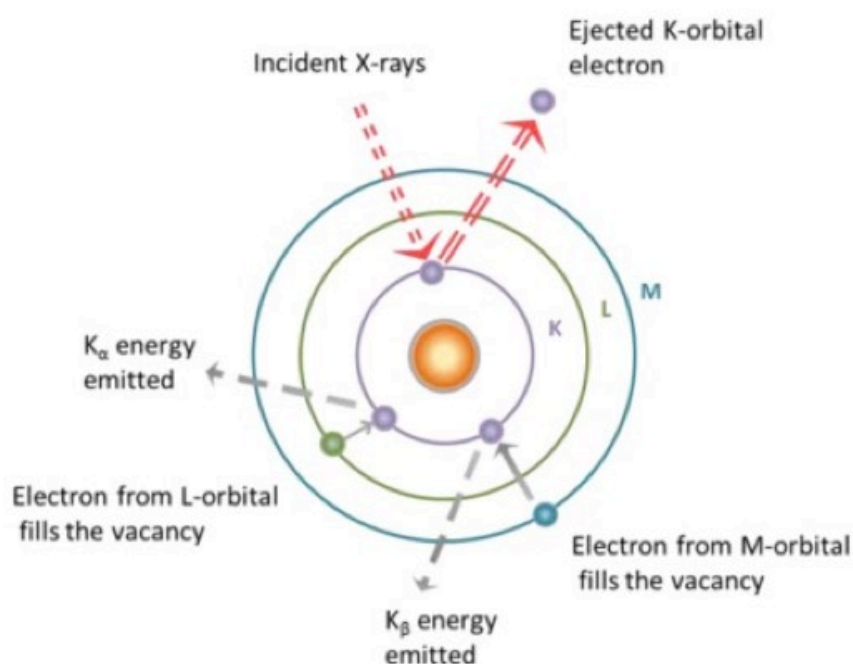
### The use of the XRF technique

The X-ray fluorescence (XRF) technique is a method used to detect metals in various types of materials. It is frequently used in e.g. metal scrap yards and to screen for metal contamination in soil. With the XRF technique, concentrations of metals are rapidly measured (typically within less than a minute) and values are most often expressed in percent.

Many of the metal measurements carried out in the BONUS CHANGE project have been performed by a newly developed XRF technique, using a handheld XRF device (see Figures 3.1 and 3.2) (Ytreberg et al., 2015). The handheld analyser was calibrated for measurement of plastic boat hulls and provides the results in concentration per square cm. This is an important advantage since it makes it possible to use the results for ranking of boats with regard to degree of contamination. Another advantages of the calibrated XRF method is that it can be used in the field, does not damage the boat and provides result within a few seconds. It is a great step forward compared to alternative methods, which require paint samples to be scraped off and sent to a lab for costly chemical analysis. The method can be utilised by e.g. environmental authorities and boat clubs, in order to detect metals on boats and also to identify boats that still have old paint layers with TBT. It thereby provides a possibility to take measures to ensure compliance with regulations and for improving the marine environment.



**Figure 3.1.** The handheld XRF instrument. In the picture, the instrument is used for measurements of soil. This application is not developed in the BONUS CHANGE project but it has been used for soil measurements in Finland and in Sweden. The principle behind the technique is explained in Figure 3.2.



**Figure 3.2.** The principle of the XRF technique is that an electron of the inner shells of an atom is excited, causing an electron from the outer shell to fill the vacancy. When this happens, energy (in the form of an X-ray photon) is released. The energy is characteristic for each element. It means that we can detect which elements are present in a specific sample. In the BONUS CHANGE project, we have focused on measuring copper (Cu), zinc (Zn), and tin (Sn) (from Bighiu, 2015).

## Screening and measuring metals on boat hulls

To investigate which boats that have OTCs such as TBT on their hulls, we have used the handheld XRF instrument (Ytreberg et al., 2015). This technique was also used to measure the amounts of other metals (copper and zinc) that could be found on boat hulls painted with antifouling paints.

## Detecting OTCs in old paint layers

By solely using the XRF instrument it is not revealed whether the tin that is found on the boat hull is in the form of OTCs and thereby could be regarded as environmentally hazardous. That is, the signal from the XRF could be detecting the harmless form of tin, i.e. inorganic tin (Sn). To rule out that harmless tin could be present on boat hulls, we needed to investigate what type of tin was present in paint layers on boat hulls. For this purpose, we developed a new method to extract OTCs from paint flakes. With this method, we could establish a correlation between the presence of OTCs and the total tin content and thus, we could draw the conclusion that the tin measured on boat hulls by the XRF was indeed OTC (see text and Figure 3.3 below).

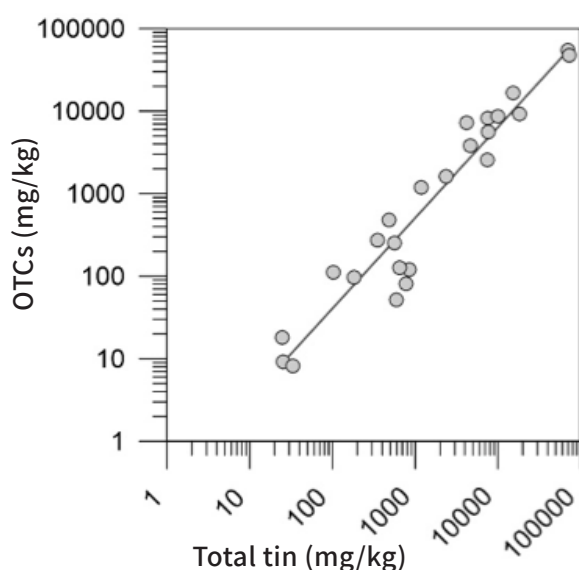
However, during the measurements on boat hulls and development of the process, we realized that the method to extract the tin itself from the paint also needed improvement. Hence, two new methods had to be developed: one for extracting the total tin from the paints and one for extracting the OTCs from the tin (Lagerström et al., 2017).

We collected 23 paint flake samples from leisure boats in Sweden, Finland and Germany. The samples were ground, sieved (<100µm) and analysed for their organotin content according to the new extraction method that was developed for this purpose.



All 23 sampled hulls were found to have organotin on them. TBT was detected in all samples, but not always as the main organotin compound. Another important finding from the study was that Triphenyltin (TPhT) was present in higher concentrations than TBT in 10 samples. The results indicate that TPhT may have been more widely used on leisure boats than what has been previously thought. In addition, we also found that other OTCs such as tetrabutyltin, which degrades into TBT in the environment, could be present in the old paint layers.

With the new methods for both the detection of OTCs and the total tin in paints, a correlation between the two could finally be investigated. The results demonstrate that the detection of tin can be used to identify boats with coatings of OTC paint since the total tin concentration was highly correlated to the concentration of OTCs (Figure 3.3). This means that we, by a simple XRF measurement, can find the boats that have old layers of organotin paint.



**Figure 3.3.** In the scraped off paint samples from leisure boats, the amount of total tin (Sn) is clearly correlated with the amount of organotin compounds (from Lagerström et al., 2017). Tin can therefore be used as an indicator for the presence of organotins.

The newly developed XRF method has also been used in another study which was performed before the BONUS CHANGE project (see Ytreberg et al., 2016). Results in that earlier study showed that 10% of about 700 measured boats across Sweden had high concentrations of tin ( $\text{Sn} > 400 \mu\text{g}/\text{cm}^2$ ) on their hulls. For comparison, one layer (40 mm dry film thickness) of a TBT-paint equals approximately  $800 \mu\text{g Sn}/\text{cm}^2$ . The findings suggest that the boats may have old coatings of organotin paint on them (Ytreberg et al., 2016). The results from the measurements produced in the BONUS CHANGE project (Lagerström et al. 2017) supports the fact that the tin observed by Ytreberg and co-authors is organotin (Ytreberg et al., 2016).

## Measuring metals in old paints layers

Through the measurement of metals, we could also conclude that copper and zinc were present on the boat hulls. There were however large variations between geographical areas. For example, measurements were made at three different areas in Sweden; on the west coast in Sweden (marine environment), in the Stockholm area (brackish water) and boats in freshwater (Lake Mälaren). Around 200 boats were measured in each area. Results from the measurements revealed that all boats on the west coast of Sweden had copper on their hull. On the Stockholm boats, copper was detected on 92 % of the boats and the percentage for the freshwater boats was 79 %. Similarly, the proportion of boats with higher copper concentrations increased with more saline water. This pattern reflects the regulation of copper in Sweden established in the 1990's implying that antifouling paints with higher copper content are only allowed on the Swedish west coast (marine waters) and not on the east coast (brackish water). The regulation



also states that no biocide containing antifouling paints may be used on leisure boats in lakes. The high proportion of boats (79 %) in the lake that still had copper on their hulls show bad compliance with this regulation. One reason might be that until now, there has been no easy way to control the metal content in the old paint layers on boats.



The study in Sweden has been followed up by similar investigations in Finland, Denmark and Germany. The preliminary results show basically the same pattern as in Sweden.

**Figure 3.4.** Picture showing the specially calibrated XRF analyser used for measurement of metals in antifouling paints on boat hulls.

## Contamination in harbours: Measuring metals in soils and sediments

In contrast to commercial ships that spend most of their time at sea, leisure boats are typically anchored in their home harbour during most of the boating season. For example, a national survey carried out in Sweden, a country with about 800 000 recreational boats, showed that the boats were anchored in their home harbour for 84 – 90% of the boating season (The Swedish Transport Agency, 2016). This means that recreational harbours and marinas are especially exposed to pollution from leaching antifouling paints, as shown by numerous studies worldwide. The metals are released from the paint into the water and bind to particles. These particles sink to the bottom and the metals eventually end up in the sediment on the seafloor of the harbour. If the sediments are stirred and moved, for example by propeller use or a current, the particles can be re-suspended and move up in the water column again. All this means that the metal concentrations in harbours sediments are very variable.

Moreover, the soil in recreational boatyards can be subjected to polluting activities such as scraping, sanding and washing of the hulls. If the soil is not properly protected, shed paint particles from the hull maintenance end up on the ground where they leach the biocides and metals contained within the paint. The removed paint particles may also be transported to the aquatic environment, since maintenance areas are typically located in direct vicinity to the water. Once in the sediments, the particles will leach biocides into the water and may also be eaten by organisms that live on the bottom of the sea floor.

In the BONUS CHANGE project, the XRF technique has been used to measure metal concentrations in several harbours. Although the technique is often used for measurements of soils, the study in BONUS CHANGE is the most extensive study of boatyards, which enabled us to, for the first time, reveal a clear link between land usage and metal pollution at the specific site (Lagerström et al., 2016). In general, our findings show that soil concentrations of copper and zinc are higher in the areas where boats are

kept and maintained compared to other areas in the boatyard used for other activities (parking, roads etc.).

Concentrations as high as 45.3 g/kg and 12.6 g/kg were detected for copper and zinc respectively and measured in one of the studied boatyards. In Sweden, this implies 226 and 25 times higher concentrations than the national respective guideline values for less sensitive land use<sup>6</sup> for copper and zinc.

The soil pollution at the investigated boatyards could be argued to be the result of “old sins”, since there are those who claim that activities such as scraping and sanding over unprotected soil no longer are on-going in boatyards these days. However, the measurements of surface soil in areas that had been used for boat storage less than 10 years clearly showed higher concentrations of metals compared to the roads and parking areas of the boatyard. Paint flakes were also readily visible on the ground at the studied boatyards in Sweden and Finland. This shows that hull maintenance activities are still being practiced without soil protection and also that the soil in boatyards can become polluted rather quickly if preventive measures are not taken. The highest concentrations of copper, zinc and lead were found on soil that had been used as boat storage for decades.



**Figure 3.5.** Examples of copper concentrations in soil from a Baltic Sea harbour. The green dots indicate that concentrations do not exceed national guidelines for ground used daily by humans whereas yellow and red dots indicate exceedance of the lower and higher guideline value, respectively.

<sup>6</sup>The limit values set for less sensitive land use (e.g. areas used for industrial purposes) allow higher levels of some substances compared to areas of sensitive land use (areas used daily by humans e.g. for housing).

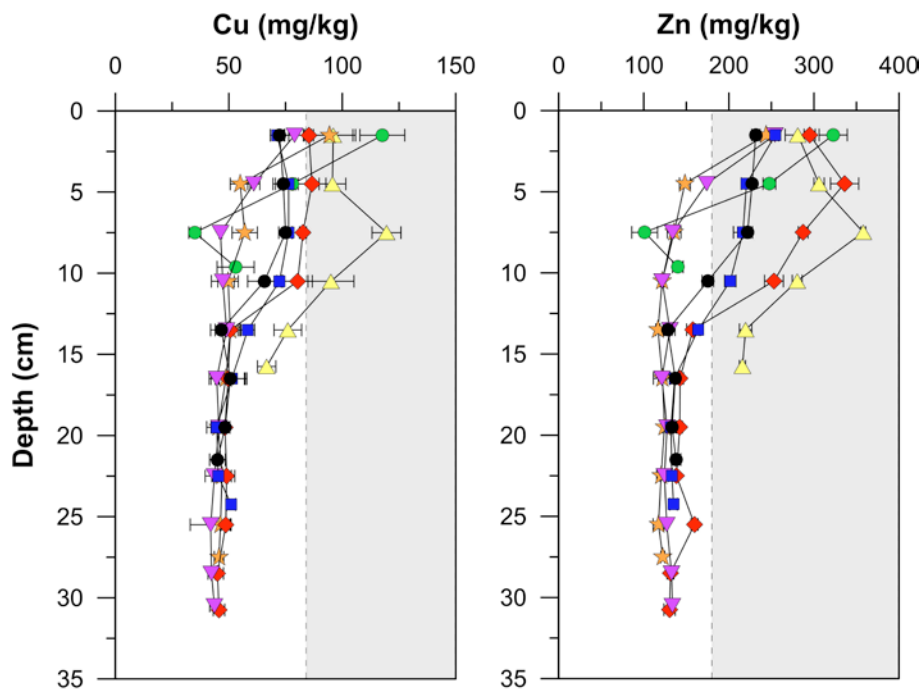




**Figure 3.6.** Examples of zinc concentrations in soil from a Baltic Sea harbour. The green dots indicate that concentrations do not exceed national guidelines for ground used daily by humans whereas yellow and red dots indicate moderately high or high values.

As indicated by the results, the soils in harbour areas (Figures 3.5 and 3.6) can be severely contaminated.

In one harbour right next to a boatyard, we also measured the metal concentrations in the sediment and how it varied depending on the sediment depth. Figure 3.7 illustrates that above 15 cm sediment depth, the concentrations of zinc and copper vary a lot. Deeper into the sediment, the concentrations are more stable. The deeper sediments were likely from the time before the recreational harbour was established in the bay. The higher concentrations in the surface sediments are likely a result of the use of antifouling paints, which have leached copper and zinc into the water.



**Figure 3.7.** Example of copper and zinc concentrations in sediment cores from a leisure boat harbour (from Lagerström et al., 2016).

The grey area shows point where concentrations exceed the Predicted No Effect Concentration (PNEC).

The findings showing high level of contaminants in soil and sediment are supported by earlier studies. For example, Eklund and co-authors' (2008; 2010) research on harbour sediments and compiled studies from coastal municipalities in Sweden, have found that recreational boatyard soils had high concentrations of copper, zinc and other compounds related to antifouling paints (Eklund & Eklund, 2014). In the BONUS CHANGE project, a similar compilation was performed in Finland. The results from the Finnish study show that fewer investigations have been performed in Finland compared to Sweden. Nevertheless, the compilation still found that the concentrations in boatyard soils are as high as in Sweden (Haaksi & Gustafsson, 2016).

## Assessing the environmental impacts in the marinas

The Baltic Sea is a stressed environment, affected by factors such as eutrophication and pollution. The salinity gradient ranges from zero in the north to around 10 PSU (Practical salinity unit) in the southern part, as compared to 25 PSU at the Gothenburg area in Kattegat.<sup>7</sup> The water exchange is limited and the time that the water remains in the Baltic Sea is quite long, about 25-35 years. Also in enclosed coastal areas (locations where e.g. piers, leisure boat harbours or marinas are located), water circulation is rather limited. This means that contaminants such as metals leaching from antifouling paints that are released in these areas persist and accumulate. As a consequence, organisms living in marinas are facing stressful conditions to which they must adapt in order to survive. However, long-term (genetic) adaptation of organisms only occurs after continuous exposure over several generations, while the input of contaminants from antifouling paints on boat hulls rather occurs in pulses, typically peaking in the summer when the freshly painted boats are launched into the water. Organisms must therefore develop tolerance to contaminants through other, non-genetic, mechanisms. Developing these mechanisms requires large amounts of energy from the organisms,

<sup>7</sup>Apart from the horizontal geographical gradient, salinity gradient could also imply that the level of salinity changes (decreases) rapidly with depth i.e. the salinity of the surface water is higher from that of the underlying water and the water close to the seabed.

meaning that normal physiological functions such as growth and reproduction may be damaged. In addition to the contaminant inputs into the marinas, other natural factors such as parasites, changes in nutrient availability or temperature could contribute to the weakening of the organisms.

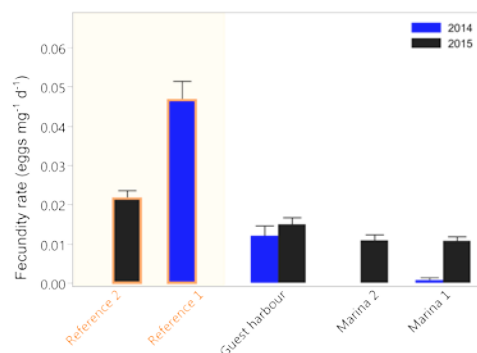
### Field studies: Exposure to antifouling contaminants causes toxicity to snails

In the BONUS CHANGE project, field experiments have been used to study the impacts of antifouling paints on marine organisms, directly in leisure boat harbours. Field experiments are a valuable method for obtaining a relevant picture of the multiple stressors in the marinas. This method has several advantages, including the possibility to manipulate the experimental setup to ensure comparable biological samples and to control the exposure time and conditions.

Gastropods (snails) represent an important link in aquatic food webs, being both grazers and predators. Snails represent the second largest group of animals, in terms of number of species. Therefore, studies on this group of animals are highly relevant for the environment. The river nerite *Theodoxus fluviatilis* (Figure 3.8) is a common and highly abundant snail in the Baltic Sea. It is not a fouling organism that attaches to the boat hulls, since it lacks free-swimming larvae. Instead, the snail is a generalist grazer feeding on algae, bacteria and other small organisms that can be found on underwater surfaces (so-called periphyton or biofilm). *T. fluviatilis* has a life-span of 2–3 years and reaches a shell length of ca 8–9 mm. The reproduction period of the snail generally peaks in the summer, which also coincides with the boating season in the Baltic Sea region. This means that snails are exposed to contaminants from antifouling paints during a very sensitive life stage. Indeed, negative effects of contaminants on snail reproduction in marinas were observed in the field experiments carried out in 2014 and 2015 in the Stockholm archipelago (Figure 3.9). For example, the fecundity decreased by up to 67 times in a marina compared to a reference location (i.e. a location not impacted by boating activities). In addition, the tissues of the snails' reproductive organs suffered from cell death (necrosis) and damaged cell membranes (lysis) to a larger extent in the marinas, compared to the reference areas. These negative effects on reproduction could potentially threaten the health of the population in the long-term.



**Figure 3.8.** *Theodoxus fluviatilis*.



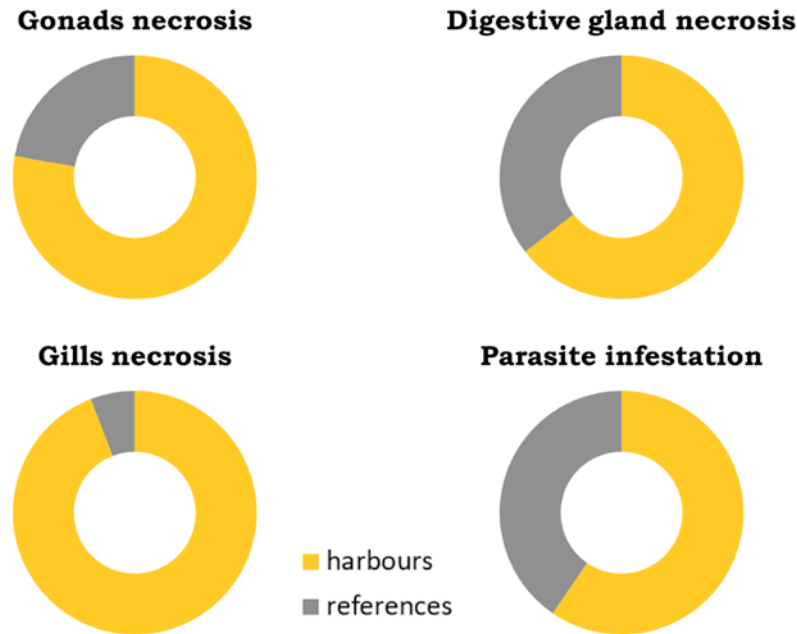
**Figure 3.9.** Snail fecundity rate; averages and standard errors.

Several other effects were also observed in the snails' tissues. These effects were observed to a higher extent among the snails in the marinas compared to the reference sites, and included alteration of the gills (dilatation and necrosis), growth of algae and fungi on the shells (fouling) and parasite infestation (Figure 3.10). Parasites (e.g. trematode larvae) were found in about half of the snails, regardless if the snails were from a marina or reference site. This problem further complicates the interpretation of the results, because it is not always possible to separate the effect of parasite infestation from the



effect of contaminants at tissue level. Nonetheless, it is important to analyse these two types of stressors together, as this is the most likely scenario in the “real” environment.

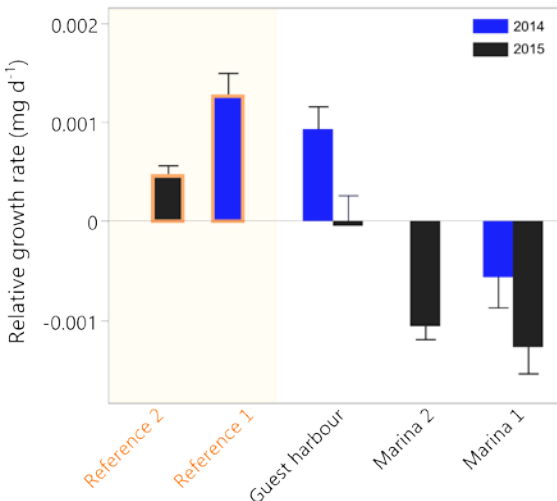
Moreover, we could see that the snails had developed several immunological responses. The responses observed were, for example, phagocytosis (a process in which one cell ingests a foreign particle), or haemocyte infiltration (haemocytes are the primary cells involved in defence against pathogens). The frequency of this type of responses in non-infested snails was generally twice higher in marinas, compared to reference sites.



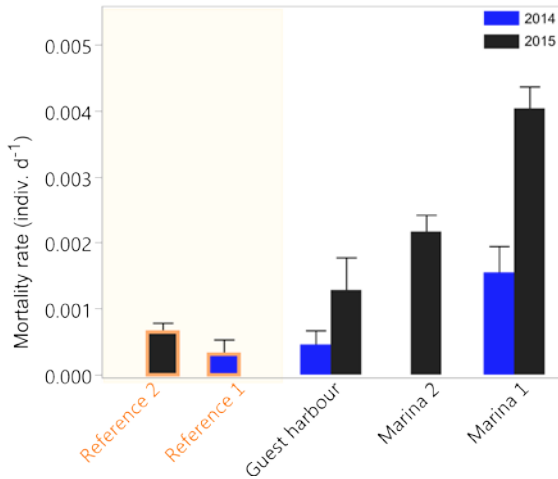
**Figure 3.10.** Examples of tissue alterations and their incidence in harbour and reference-exposed snails.

The growth of the snails was also significantly lower in the marinas, compared to the reference areas (Figure 3.11). This might be an indication that under stressful conditions, such as contaminant exposure, the snails direct their energy to other metabolic processes than growth.

The survival of the snails was substantially lower in all the marinas, compared to the reference areas (e.g. up to 6 times lower) (Figure 3.12).



**Figure 3.11.** Snail growth rate; averages and standard errors.



**Figure 3.12.** Snail mortality rate; averages and standard errors.

Metallothionein (MT) is a protein that is involved in the metabolism of essential metals and is generally produced in larger amounts in organisms that live in environments that have been contaminated by metals. The snails from marinas had high levels of MT, which is probably indicating their attempt to detoxify. However, snails from the reference sites also had relatively high levels of MT, which might be related to physiological processes such as reproduction. To better interpret this result, we would need more research on the background levels of MT that the snail species *T. fluviatilis* has under normal physiological conditions. Currently, this is the only study that has investigated MT in this species.

Metals such as copper and zinc were associated with the majority of the toxic effects observed in the snails. For example, high levels of dissolved copper were related to low fertility and high mortality. High levels of dissolved zinc were associated with low growth rates of snails. Both metals increased the probability of tissue alterations in several organs, such as destruction of cell membranes and cell death (lysis and necrosis) in the gills and the digestive gland. The link between metals and toxic effects, as well as the proximity to leisure boats, indicate that antifouling paints contribute to the observed effects. Important to note is also that the contribution of other contaminants has not been measured in this study and thereby remains unknown.

### Laboratory study: Behavioural changes of snails caused by antifouling contaminants

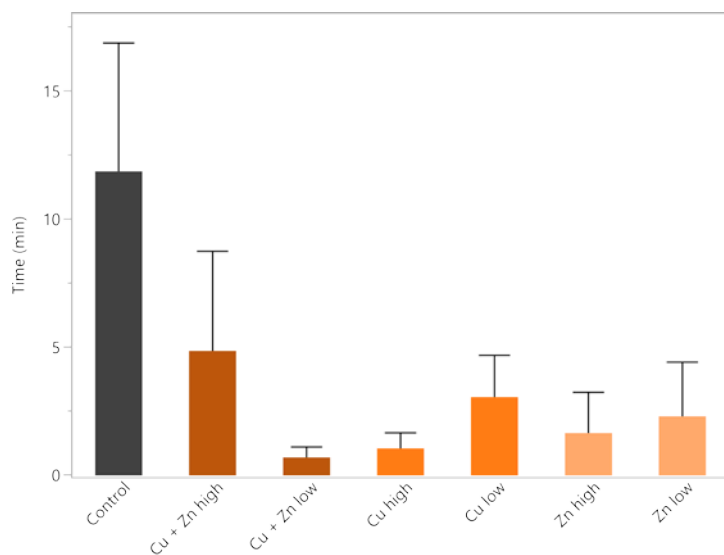
Behaviour is an important aspect of an animal's ecology. Changes in behaviour are some of the most sensitive indicators of environmental disturbance and are used as 'early warning' signals to assess environmental quality. Behavioural changes are highly relevant, as they can affect normal processes such as feeding, mating and predator avoidance, with severe consequences at the community level. Therefore, apart from the field experiments, we also wanted to assess the effects of copper and zinc, as well as their mixture, on the behaviour of a marine organism.

Laboratory studies on the snail *T. fluviatilis* were carried out to investigate how the intake of contaminated food (biofilm) affects the snails' crawling and feeding behaviour. We used a biofilm spiked with high and low metal levels to feed the snails.<sup>8</sup> The quality, i.e. the health of the algae, in the biofilm was measured as photosynthetic efficiency and was found not to differ between contaminated and control treatments.

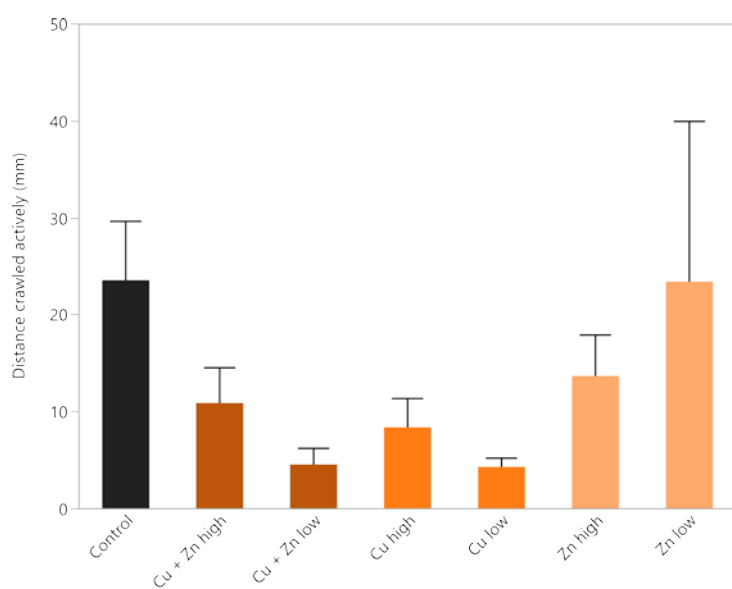
The results show that snails fed with contaminated biofilm began their active movement faster than snails fed with uncontaminated biofilm (Figure 3.13). This might suggest either an increased boldness of the snails from the contaminated treatment, or their attempt to change place and find better conditions. Moreover, the snails fed with uncontaminated biofilm crawled a greater distance compared to snails fed with biofilm spiked with low levels of copper, or copper and zinc mixed at low concentration (Figure 3.14). Surprisingly, there was no difference in the amount of food eaten by the snails from different treatments (i.e. biofilms with low or high metal levels) (Figure 3.15). A possible interpretation of this result can be that the snails were unable to distinguish between clean and contaminated food. In a long-term perspective, this can lead to accumulation of high metal concentrations in the snails. These high metal levels can then be transferred to the animals feeding on the snails, thus becoming problematic for higher trophic levels.

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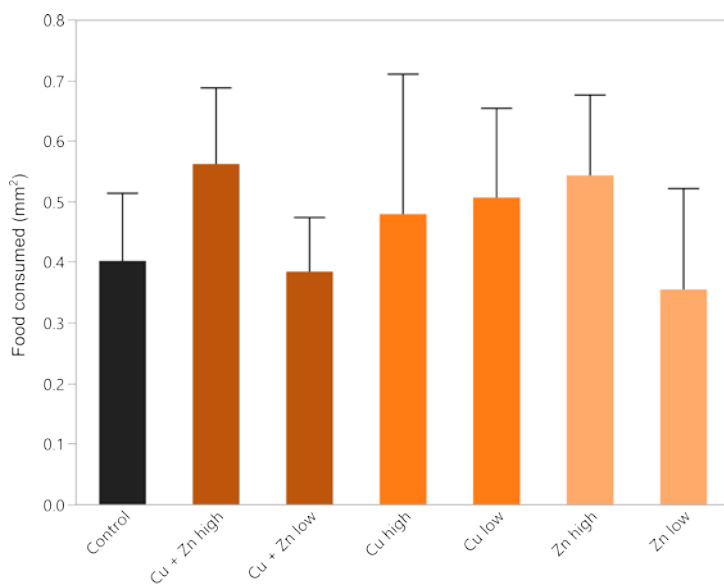
<sup>8</sup> The low levels were ~10 µg/L Cu and ~70 µg/L Zn and the high ~100 µg/L Cu and ~600 µg/L Zn.



**Figure 3.13.** Time to first active snail movement on biofilm spiked with different metal concentrations and uncontaminated (control) biofilm; averages and standard errors.



**Figure 3.14.** Distance crawled actively by snails on biofilm spiked with different metal concentrations and uncontaminated (control) biofilm; averages and standard errors.



**Figure 3.15.** Areas of contaminated and uncontaminated biofilm eaten by snails; averages and standard errors.

## Concluding remarks

In this chapter, we have described results from BONUS CHANGE project showing that the use of antifouling paints containing biocides has a number of environmental impacts. Although the use of the toxic biocides TBT and TPhT has been banned, we found that there is still a high prevalence of boats with old paint layers containing these substances, as well as other OTCs. We have moreover refined and developed the methods to extract and quantify the OTCs in paint flakes. By using the XRF technique, we showed how screenings of boat hulls can give quick results for detecting tin as an indicator for OTCs and other metals such as copper in paint layers on the boat hull. It thereby provides the possibility to detect boats that need to seal or remove organotin paints from the hull.

Another important result from the studies worth to highlight is that we have found more than ten different OTCs on boats. Since all of them have toxic properties, they should not be spread in the marine environment. In some locations, TPhT was for example more common on boat hulls than TBT. It is therefore important to not look only for TBT because there is a risk that one underestimates the problem of toxic organotin compounds.

Recreational harbours can be subjected to polluting activities such as scraping, sanding and washing the hull. From our research, we could show that contamination in harbours is still a present problem around the Baltic Sea. High levels of copper and zinc were found, especially at sites where boat storage and maintenance activities take place. High levels of metals were found in the soil in areas that have been used as a harbour for less than 10 years. These findings illustrate that the contamination is not only a result of old sins. Instead, the soil in boatyards can become polluted quite quickly if the ground is not properly protected.

Last but not least, we present findings showing that biocides used in antifouling paints severely affect marine organisms. Studies, both in the field and in the laboratory, have given us evidence of the toxicity of copper and zinc. In particular, the field studies showed the most pronounced effects on snails, probably due to the longer exposure time to copper and zinc. These results tell us that long-lasting exposure to antifouling contaminants, together with other stressors that are naturally found in the environment (e.g. parasites), leads to a number of negative impacts on marine organisms. The observed effects included tissue alterations, reductions in growth and reproduction and ultimately reduced survival of the *T. fluviatilis* snail species. The findings highlight the need to reduce the current input of antifouling biocides into the Baltic Sea. Together with the evidence that paints with low copper concentrations can be highly efficient against biofouling (see Chapter 4), we argue that the current antifouling paints constitute an environmental risk that way exceeds the benefit of this practice.



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## Chapter 4

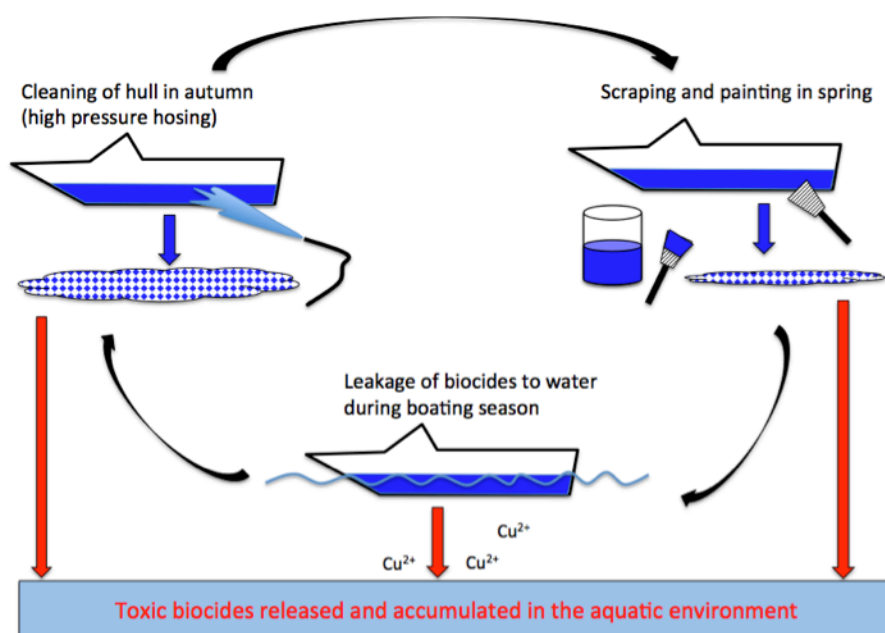
### We can change products and infrastructures but not marine organisms

*Anna-Lisa Wrangé, Magnus Dahlström, Mia Dahlström, Ann-Kristin Eriksson Wiklund, Bianca Koroschetz, Maria Lagerström and Burkard Watermann*

An astounding 3-3.5 million boats have their homeports in the countries bordering the Baltic Sea. To avoid fouling on the hull, the first method of choice for most leisure boat owners are using traditional toxic antifouling paints containing copper and zinc. Because of this, leisure boat antifouling practices contribute to the high levels of contaminants in the Baltic Sea.

A typical antifouling paint erodes slowly over time, giving rise to a slow but controlled release of biocides to the water. Many boat owners choose to use paints containing high amounts of copper (22-35% wet weight (w/w)), this means that the paint contains more copper than is depleted from the paint during a boating season. In addition, most boat owners re-paint their boat hull each year, resulting in a high accumulation of copper on the hull.

Yet, the problem of antifouling toxins spreading to the marine environment is not limited to their release from the painted hull when the boat is placed in the water, but also from maintenance practices (e.g. scraping, sanding and washing or high-pressure hosing of the hull). Without sufficient waste collection, the paint flakes containing toxic heavy metals end up on the ground and are further transported to the ground water or to the sea close to the marina, contributing to the overall spread of toxic metals in the coastal environment (as illustrated in Figure 4.1). This results in high contamination of soils in areas where boats are stored and maintenance work is performed, as well as contributing to the overall spread of toxic metals in the coastal environment with negative effects on marine organisms living in coastal areas and marinas (see previous Chapter 3).



**Figure 4.1.** Pollution sources of copper (and other antifouling toxins) from the boat maintenance cycle, when high copper containing paints are used in combination with insufficient protection of the ground during maintenance work.

The use of toxic antifouling paints and the maintenance practices result in a continuous input of toxins to shallow coastal environments (Figure 4.1). In this chapter, we set out to gather information to help solve this problem. Firstly, we describe fouling and fouling pressure in the Baltic Sea and evaluate the relative performance of high vs. low copper-based antifouling paints. Our findings show that many of the paints used today are excessively toxic, i.e. copper concentrations in antifouling paints can be reduced drastically and still perform equally well in the Baltic Sea. Secondly, we can show that there is no correlation between the copper oxide content and the release of copper, and that release of copper is strongly affected by environmental conditions including salinity. Furthermore, we describe a number of biocide-free antifouling techniques and present results from evaluation of the performance of different antifouling techniques. The evaluation illustrates that many of the biocide-free antifouling techniques have excellent performance in combating antifouling. Moreover, we shed light on marina infrastructure that is needed in order to hinder the spread of antifouling toxins from maintenance work. Finally, yet importantly, we show that by changing our choice of antifouling method, i.e. reducing the use of toxic paints and investing in more environmentally friendly alternatives, it is possible to reduce the release of toxic antifouling substances significantly in coastal areas of the Baltic Sea without causing problems for leisure boat owners.

## **Fouling pressure and performance of copper-based antifouling paints**

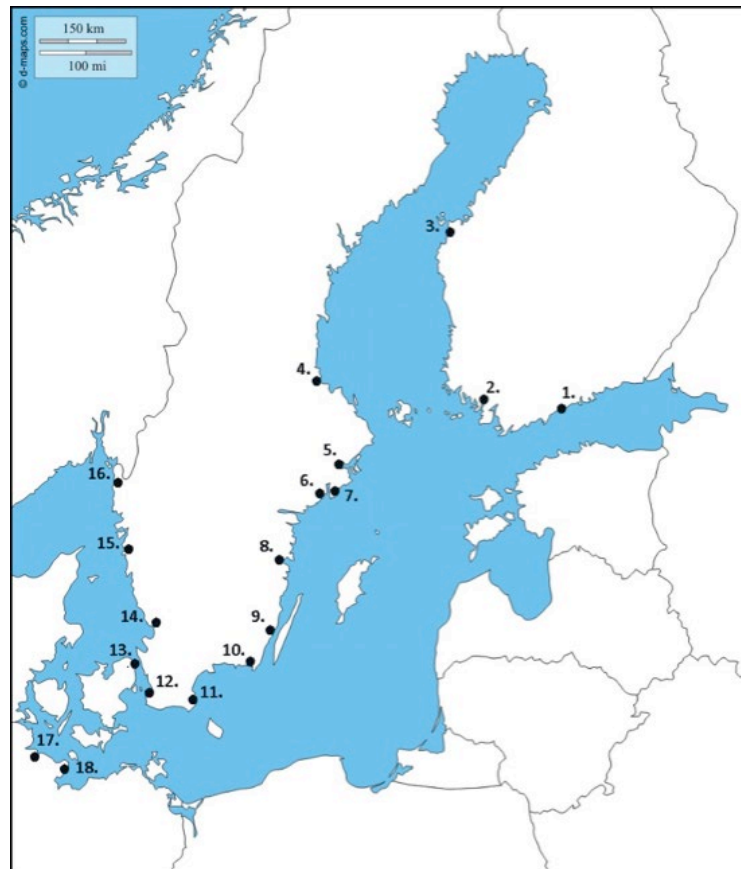
The authorization of antifouling products by competent authorities differs between Member States in the European Union, and among the countries bordering the Baltic Sea. For example, paints with toxic high copper content (e.g. in the range of 35% (w/w)) are allowed on leisure boats in Finland, Denmark and Germany, but not along the Baltic coast of Sweden even though these countries share the same sea. In light of this situation, we wanted to evaluate if the use of highly toxic antifouling paints on leisure boats can be motivated in the first place. The questions that we asked were: What type of fouling can we find in the different regions of the Baltic Sea? Is this fouling equally intense throughout the Baltic Sea and does it change over seasons? Can antifouling paints with low copper content, like the ones allowed in Sweden, work across all regions in the Baltic Sea? If the degree of fouling is generally lower in the Baltic Sea compared to strict marine waters like the North Sea and if it is possible to show that low copper containing antifouling paints and biocide-free alternatives perform well, such findings would support a more restrictive authorization of antifouling paints, like the one in Sweden. This would serve to protect sensitive coastal waters and reduce the negative impact of unsustainable antifouling practices in the Baltic Sea.

In the BONUS CHANGE project, we have collected data on the natural fouling pressure (intensity) throughout the Baltic Sea area during four boating seasons. Furthermore, we have evaluated performance of five different commercial antifouling paints with varying copper oxide ( $\text{Cu}_2\text{O}$ ) content ranging from 7% to 35% (w/w), over several years. We have also tested efficacy of paints containing even lower copper oxide concentrations than currently available on the market, down to 4.3% (w/w) with the aim to gather thorough scientific evidence on their performance, findings which could contribute to reduce the release of toxic antifouling substances in coastal areas of the Baltic Sea.

## Using panels to study fouling and paint performance

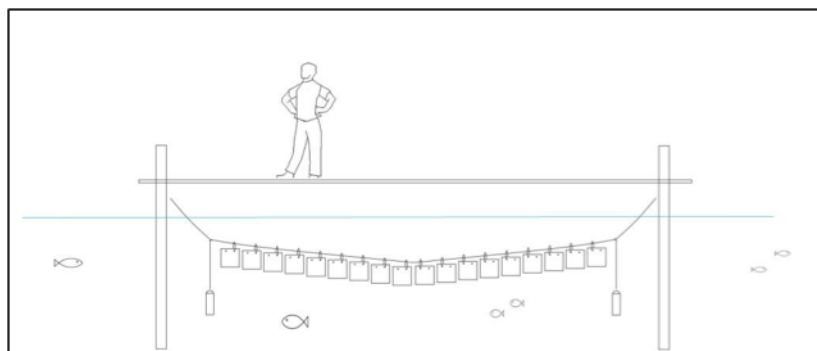
The availability of hard surfaces for aquatic organisms to settle and live on in the sea is very limited. At the same time, there are massive numbers of free-swimming larvae and spores in the water searching for surfaces to live on. Therefore, every new surface submerged in the sea is more or less instantly conditioned and colonized by fouling organisms. By placing panels in the sea during a boating season, it is possible to study what fouling species colonize the panel in that specific location and how the fouling develops during the season. Static panels may first seem unsuitable to mimic boat hulls. However, the majority of boats are more or less stationary in the marina during the boating season. A boat spends about 85% of the time at berth in the marina (Lagerqvist & Andersson, 2016). Thus, static panels are simple and highly relevant for monitoring fouling pressure as well as studying antifouling performance of painted panels.

We performed our field studies during four consecutive boating seasons (May-October; 2013-2016). We attached panels (15x15cm) to lines and placed them vertically at 1m water depth at 18 different sites around the Baltic Sea (Figure 4.2). In most cases, they were hanging from jetties in leisure boat marinas (Figure 4.3).



**Figure 4.2.** Study areas where field panels were placed in marinas during 2013-2016; 1-Helsinki; 2-Turku; 3-Vaasa; 4-Gävle; 5-Bullandö; 6-Askö; 7-Nynäshman; 8-Västervik; 9-Kalmar; 10-Karlskrona; 11-Simrishamn; 12-Malmö; 13-Helsingör; 14-Halmstad; 15-Fiskebäck; 16-Strömstad; 17-Kiel; 18-Grömitz.





**Figure 4.3.** Illustration of placement of the different field panels from jetties in the marinas.

To document the natural fouling pressure, we used two different types of biocide-free panels<sup>9</sup> in the different marinas (Figure 4.3). We also evaluated the antifouling performance of five different commercial antifouling paints. The paints represent low, medium and high copper content ranging from 6.9% to 34.6 w/w % copper oxide. These paints represent a range of antifouling paints that are available to boat owners along the Baltic Sea coasts (Table 4.4). The aim was to see if low copper containing paints are equally efficient as paints with medium or high copper content.

**Table 4.4.** Commercial antifouling paint used in the study. \* = Paints not approved in Sweden for use on the Swedish Baltic Sea coast from Örskär to Trelleborg.

| Paint                            | Type of paint              | Copper oxide (% w/w) | Zinc oxide (% w/w) |
|----------------------------------|----------------------------|----------------------|--------------------|
| transparent PMMA (Plexiglas)     | unpainted                  | 0                    | 0                  |
| International Lago racing        | biocide-free               | 0                    | 0                  |
| Hempel Mille Light Cu            | Rosin-based                | 6.9                  | 10 - 25            |
| Biltema Baltic Sea               | Rosin-based                | 7.5                  | 20 - 25            |
| International Cruiser One        | Rosin-based                | 8.5                  | 10 - 25            |
| Biltema Antifouling West coast * | Rosin-based                | 13                   | 15 - 20            |
| Hempel Mille Xtra *              | Self-polishing paint (SPC) | 34.6                 | 10 - 25            |

Moreover, we investigated if the antifouling performance of the paints varied depending on the location. As can be seen on the map (Figure 4.2), the test sites were located in various regions around the Baltic Sea, representing partly different environmental conditions including salinity and temperature.

Finally, we investigated if the copper oxide content of antifouling paints could be reduced even further compared to the antifouling paints that are available on the Swedish market today, i.e. below 6.9%, without compromising antifouling efficacy (Table 4.5). This was done by painting panels with a generic non-toxic antifouling paint, to which we added different copper and zinc concentrations, namely; 2.6, 4.3, 6.1 and 8.5 w/w % copper oxide, combined with 0, 10 or 20 % zinc oxide. Panels were placed at six different locations in 2015, and three locations in 2016, around the Baltic Sea (Table 4.5). At the end of each boating season, all panels were retrieved and photographed. The fouling composition and intensity (percentage coverage of different fouling groups) was then analysed on each panel.

<sup>9</sup>Sanded transparent Plexiglas© panels and panels painted with a black biocide-free commercial antifouling paint called Lago racing.

**Table 4.5.** The generic paint with addition of low amounts of copper oxide (2.6 - 8.5% Cu<sub>2</sub>O). All concentrations, except the highest one (8.5%) are below what is available on the market today. The panels were exposed in Strömstad, Fiskebäck, Simrishamn, Bullandö, Helsingfors and Vaasa in the summer of 2015 and in Fiskebäck, Bullandö and Helsinki in 2016. (Note: The 2.6% panels were unfortunately lost after 56 days due to harbour work).

| Copper oxide content (% w/w) | Zinc oxide content (% w/w) | Exposure time in the field (days) | Locations                               |
|------------------------------|----------------------------|-----------------------------------|---|
| 2.6                          | 0, 10, 20                  | 56                                | Fiskebäck (2016)                        |
| 4.3                          | 0, 10, 20                  | 150                               | 6 locations (2015) + 3 locations (2016) |
| 6.1                          | 0, 10, 20                  | 150                               |   |
| 8.5                          | 0, 10, 20                  | 150                               |   |

## Fouling types and fouling pressure in the Baltic Sea

When we talk about fouling pressure, we mean the amount of marine organisms that attach to a clean hard surface placed in the sea during a certain period of time (defined as the percentage surface coverage of a panel). Another distinction concerns *what type* of fouling that is present. The marine organisms that attach to hulls can be divided into “soft” and “hard” foulers. The former group includes organisms with hard calcareous or siliceous shells or structures such as barnacles whereas the latter group includes e.g. algae or hydroids (see Figure 2.2 in Chapter 2 for photos of fouling organisms). While hard foulers are considered more problematic as they are difficult to remove from boat hulls, soft fouling more easily detaches from surfaces when the boat makes speed through water or when the boater performs maintenance work on the hull.

The panel tests showed, as expected, that the overall fouling pressure was generally lower in the Baltic Sea compared to marine waters in the Kattegat and the Skagerrak. In consequence, the general need to use of toxic antifouling products can also be considered lower. However, we found some variation between marinas and between years, demonstrating that it is not always easy to predict exactly what type of fouling that will occur in a specific location (Table 4.6). Many factors including environmental conditions such as salinity, temperature and currents affect the timing of recruitment and intensity of fouling organisms (Fraschetti et al., 2002). Other factors caused by human activities, such as eutrophication, pollution and modified habitats, can also affect the fouling intensity (Lawes et al., 2016; Lawes et al., 2017).

By collecting monitoring data over multiple years as we have done in the BONUS CHANGE project, we are able to identify patterns in fouling composition and variation, patterns that are not possible to detect from studies covering only one or two seasons. For example, we could identify that barnacles dominated the fouling on the Swedish west coast (Strömstad and Fiskebäck/ Gothenburg), but also at some sites within the central Baltic Sea including Turku (FI) and in the southern Baltic Sea in Karlskrona (SE). These sites can be classified as so called “hotspots” for barnacle fouling.

**Table 4.6.** Table A) shows variation in fouling between years of hard fouling (fouling species with calcareous shells, including barnacles, mussels, tubeworms and bryozoans) and table B) shows variation in fouling between years of barnacles only. Both tables include all studied locations in the Baltic Sea region during three consecutive years (the colour indicate the mean % coverage of fouling on the panel). Kiel is not included due to missing data from one year.

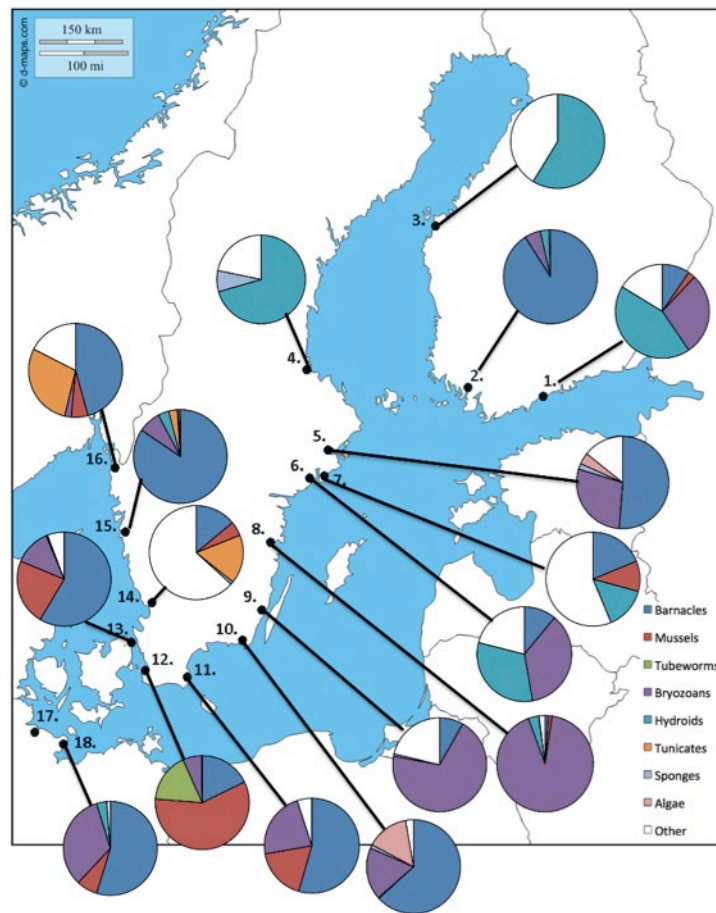
| Location   | A. Hard fouling |      |      | B. Barnacle fouling |      |      |
|------------|-----------------|------|------|---------------------|------|------|
|            | 2014            | 2015 | 2016 | 2014                | 2015 | 2016 |
| Strömstad  |                 |      |      |                     |      |      |
| Fiskebäck  |                 |      |      |                     |      |      |
| Halmstad   |                 |      |      |                     |      |      |
| Helsingör  |                 |      |      |                     |      |      |
| Malmö      |                 |      |      |                     |      |      |
| Grömitz    |                 |      |      |                     |      |      |
| Simrishamn |                 |      |      |                     |      |      |
| Karlskrona |                 |      |      |                     |      |      |
| Kalmar     |                 |      |      |                     |      |      |
| Västervik  |                 |      |      |                     |      |      |
| Askö       |                 |      |      |                     |      |      |
| Nynäshamn  |                 |      |      |                     |      |      |
| Bullandö   |                 |      |      |                     |      |      |
| Gävle      |                 |      |      |                     |      |      |
| Vaasa      |                 |      |      |                     |      |      |
| Turku      |                 |      |      |                     |      |      |
| Helsinki   |                 |      |      |                     |      |      |

| Percentage cover of panel |         |
|---------------------------|---------|
|                           | 0%      |
|                           | 1-20%   |
|                           | 20-50%  |
|                           | 50-80%  |
|                           | 80-100% |

Along the southeastern part of the Swedish coast, the crust-forming bryozoans (type of hard fouling) seemed to be more dominant in the fouling community, whereas hydroids (soft fouling) were more common in the northernmost parts of the Baltic Sea (Figure 4.7). In contrast to the “barnacle hotspots”, there were also sites that generally had very low fouling during all years. Examples include Kalmar and Gävle (Sweden) where the fouling mainly consisted of soft fouling. This provides good support for phasing out biocide-based antifouling all together in these areas. In such locations, biocide-free techniques could easily be used and perform very well.

Moreover, harbour characteristics such as water exchange rates and turbidity may also potentially affect the fouling pressure. However, this was not investigated in detail within the BONUS CHANGE project. Based on the parameters that we have included in our analyses (salinity and temperature, water volume and number of boats in the marina), we can see that salinity is the main factor influencing the intensity and type of fouling that is present on the panels.



**Figure 4.7.** The map shows the variation in fouling that was present on the biocide-free panels at the 18 locations studied in 2016, shown as percentage of coverage of different species groups, including barnacles, mussels, tubeworms, bryozoans, tunicates, sponges and algae.

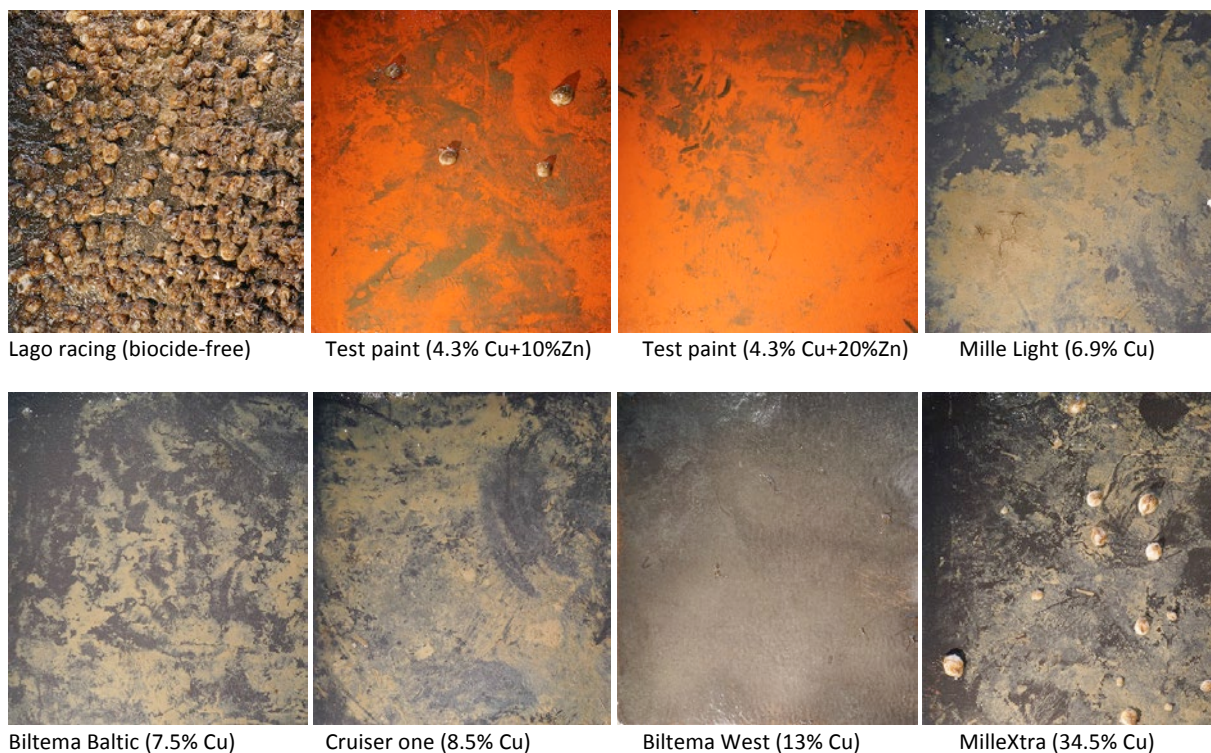
### Low copper paints show full antifouling performance

From the panel tests, we found that the commercial antifouling paints containing low concentrations of copper (7.5% copper oxide) completely resisted fouling of barnacles throughout the Baltic Sea as studied over several seasons, including in marine waters in Kattegat (Fiskebäck/Gothenburg), a hotspot marina for barnacle fouling (Figure 4.8). Only in the Skagerrak area (Strömstad), there was some fouling on the 7.5% panels, although to a much lesser extent than on the biocide-free panels. The 6.9% paint was also highly efficient at most locations compared to the control panels, but had some fouling present (1-10% cover) at a few locations in the south-western Baltic Sea.

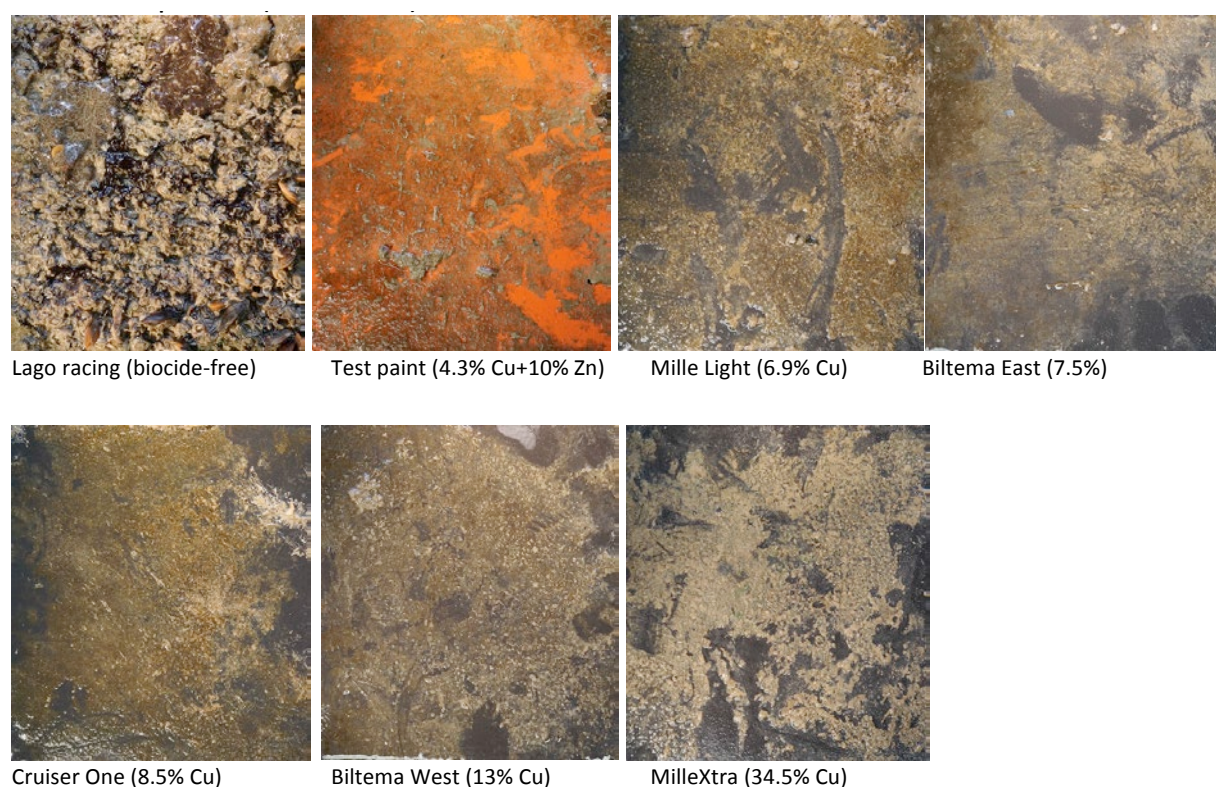
Furthermore, the panels painted with even lower copper and zinc concentrations than available commercially today, showed that a copper concentration of 4.3 w/w % (with 10%-20% zinc oxide) is highly efficient against barnacle fouling in the Baltic Sea and Kattegat (see red panels Figure 4.8). Clearly, copper concentrations in antifouling paints can be reduced drastically in the Baltic Sea and still perform equally well as high copper content paints in the range of 35% copper oxide (w/w).



### Photos of panels (Vaasa):



### Photos of panels (Fiskebäck):



**Figure 4.8.** The pictures show examples of fouling on panels painted with antifouling paints with different copper oxide content (0-35%) after 5 months in the northern Baltic (Vaasa in Finland), and from Fiskebäck/Gothenburg in the Kattegat (Swe), during 2015. Both locations were dominated by hard fouling organisms (mainly barnacles). In Fiskebäck (Kattegat) all the paints containing copper were efficient against macroscopic fouling (i.e. all types of fouling except slime and silt, which is visible on all panels). Biltema BS (7.5% Cu<sub>2</sub>O) performed equally well as the high copper containing paint Hempel Mille Xtra (34.6% Cu<sub>2</sub>O). In Vaasa (northern Baltic Sea), most commercial paints performed well, except Mille Xtra, which is partly explained by the low salinity in the water, which reduces the release of copper from the paint.

## What determines how well an antifouling paint works?

There is a general misconception that the more copper you add to an antifouling paint, the better it will withstand fouling. However, it is not the copper content in the paint per se, but the release rate of copper (i.e. the speed at which copper is released from the paint to the surrounding water) that determines how well a paint prevents fouling. The release rate is expressed as the amount (in  $\mu\text{g}$ ) of copper released per square centimetre and day ( $\text{cm}^{-2} \text{ day}^{-1}$ ). To ensure efficiency against fouling organisms and that the paint is effective for a long time (i.e. has a long service lifetime), marine antifouling paints are designed to release biocides slowly (Kiil et al., 2001; Thouvenin et al., 2002).

There are several factors related to the specific ingredients and formulation of the paint that influences the release rate of copper, e.g. the composition of the binder in the paint and its ability to take up water. When designing the paint, these factors are modified to control both the rate of release of the biocidal ingredients and the erosion of the paint film (Gopferich, 1996; Kiil et al., 2001; Thouvenin et al., 2002). Moreover, environmental factors must be considered in the composition of the paint, because they also affect the release rate, such as temperature and salinity (Yebra et al., 2004). In general, low salinity in the water (about 5 PSU, Practical Salinity Unit) will result in decreased release rates of copper compared to more saline waters ( $>15$  PSU) (Ytreberg et al., 2017).

In contrast to copper, the release rate of zinc from the studied paints in our panel tests was not affected as much by salinity, but was shown to be paint specific, emphasizing the complexity further (Lagerström et al., *in press*). In addition, we have shown that zinc oxide per se affects the release of copper from the paint (Lindgren et al., *submitted manuscript*). Furthermore, based on the five studied commercial paints in BONUS CHANGE, no correlation between the copper oxide content and the release of copper could be found (Lagerström et al., *in press*). The copper oxide content of an antifouling paint is therefore not a good predictor of copper release rate. These results highlight the importance of taking the entire paint composition as well as environmental conditions into account, rather than just focus on the copper content of the paint.

## Methods used to estimate release rates from antifouling paints

In the European Union, biocide containing antifouling paints must pass an environmental risk assessment performed by the competent national authority before it is released on the market. Included in the risk assessment is evaluation of the paint's release rate, meaning that a paint is not allowed if it releases unacceptable amounts of e.g. copper as this would pose unacceptable environmental risks.

Several methods exist to determine the biocide release rates from antifouling paints. In the EU and elsewhere, the most commonly used methods for release rate determination is the CEPE mass-balance (MB) method and the laboratory-based rotating cylinder method (RC). In the CEPE mass balance method (CEPE, 2003) no actual measurements or tests of release rates need to take place since it is merely a mathematic calculation based on parameters such as the paint thickness, the lifetime of the paint and the biocide content of the paint. Since the paint manufacturers are not obliged to show any release rates measured in the field, the competent authorities who perform the risk assessment of the antifouling paint (e.g. KEMI in Sweden, Tukes in Finland) cannot control if the release rate submitted in the environmental risk assessment reflects actual field conditions or not.



The other commonly used method to estimate release rates from antifouling paints, is the laboratory based Rotating Cylinder method (ASTM, 2005). This is a laboratory method primarily developed to screen experimental coatings during the manufacturer's product development process. Thus, it has not been developed to provide reliable data to use in environmental risk assessment, nor for regulatory purposes.

There have also been attempts to develop field-based methods e.g. the "Dome method". However, this method has entailed practical and economical challenges (diving etc.) so it has never been recommended as a standardized method for environmental risk assessment (Finnie, 2006).

In addition to estimating the release rate using one of the described methods, correction factors are routinely applied since it is widely accepted that the two main methods overestimate the total release of copper from antifouling paints (Finnie, 2006). Thus, when using the CEPE mass balance method a correction factor of 2.9 may be applied and when using the rotating cylinder method, a correction factor of 5.4 may be applied.<sup>10</sup> However, the correction factors are primarily based on a single scientific study (Finnie, 2006), using the results from one paint, which is not representative of all paint types available on the market today. Furthermore, there is no consistency in regards as to which of the two standard methods (MB and RC) should be used for which element (zinc and copper). The paint companies can choose to use either or both methods in their dossier when applying for authorization of a new product.

In BONUS CHANGE we have used a newly developed technique for estimating release of copper under field conditions from antifouling paints taking use of the analytical instrument X-ray fluorescence (XRF) (Ytreberg et al., 2015; Ytreberg et al., 2017). The method is not new per se; it has previously been used to measure metal content in e.g. soils (Melquiades & Appoloni, 2004). However, the application for antifouling paints coated on Plexiglas panels is new (Ytreberg et al., 2017; Lagerström et al., *in press*). One of the advantages of this method is that it is possible to identify environmental field parameters that influence the release of copper from paint. It could thereby be used to provide more realistic release rates of antifouling paints under different environmental conditions such as for example different salinities and water temperatures. As a consequence, the XRF can also be used to design more optimized antifouling coatings, aiming for paints that are efficient but not causing unnecessary negative effects to the natural environment (i.e. identifying the minimum release of copper necessary to avoid fouling in different geographical regions).

### How much copper is released from antifouling paints?

Based on the field studies performed in the BONUS CHANGE project, we have estimated the amount of copper that is released per square centimetre and day ( $\mu\text{g cm}^{-2} \text{ day}^{-1}$ ) from different paints during a boating season (that still show good performance in deterring fouling). It is important to note that we cannot define a cut-off value for the lowest copper release rate possible that still deters fouling based on these results for several reasons. For one, our results show that the release rate is not constant over time, and is affected by environmental conditions, making it difficult to predict what release rate a paint will actually have when used by the boat owner.

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<sup>10</sup>The correction factor basically implies that the release rate derived from either the MB or the RC method is divided by 2.9 respectively 5.4, resulting in a much lower (corrected) release rate.

Another important point is that that current authorisation of antifouling paints in e.g. Sweden is based on release rate estimates that are calculated using methods that are questionable for a number of reasons (Lagerström et al., *in press*). In brief, the current standardised methods underestimate the “true” release rates under field conditions. We can show that when using the current limit values defined to pass the risk assessment in Sweden, several antifouling paints currently available on the market would not be authorised based on the release rates that we have measured (Lagerström et al., *in press*).

Within BONUS CHANGE we have quantified the release rate for several commercial paints studied in both medium and low salinity environments. In medium salinity (14 PSU in Fiskebäck, Kattegat) we found that commercial paints containing 7-35% copper oxide released between 5-11  $\mu\text{g cm}^{-2} \text{ day}^{-1}$  (Lagerström et al., *in press*). In contrast, the same commercial paints had release rates between 3.3 - 5  $\mu\text{g cm}^{-2} \text{ day}^{-1}$  inside the Baltic (at a salinity of 5 PSU), highlighting once again the influence of salinity on release rates. All these paints were effective against fouling during a full season (150 days). These results show that it is possible to reduce the release rates of copper in antifouling paints to meet the lower end of these ranges (3.3 – 5  $\mu\text{g cm}^{-2} \text{ day}^{-1}$  described above), without affecting the antifouling efficacy. Furthermore, it is possible that release rates below these ranges are efficient in deterring fouling too, however this requires further evaluation.

### Ways to avoid excess of biocides in future antifouling paints

There is ample scientific evidence from studies performed within BONUS CHANGE that excessive amounts of copper are present in current commercial antifouling paints. Not only are the copper release rates unnecessarily high for some products, i.e. more copper is released than what is needed for fouling protection (Lagerström et al., *in press*), but the specified lifetime of the products is generally not representative, leading to needlessly high frequencies of re-painting. The latter leads to build-up of copper on boat hulls, and ultimately, pollution of boatyard grounds.

Provided that a product both passes the environmental risk assessment and can provide evidence of antifouling efficacy, future authorization of antifouling paints should also require paint producers to show that their product does not contain excessive amounts of copper. The specified lifetime of the product should be shown to be realistic i.e. if the recommended life span of the paint is one season (5 months), manufacturers must show that the majority of the copper is used up during that time, i.e., serves its antifouling function while the boat is in the water. This is not a requirement today. As the release rates of copper, and sometimes zinc are salinity-dependent, the lifetime of the paint will be dependent on the location of use. Through determination of release rates under field conditions reflecting the intended use of the product, more realistic recommendations regarding product lifetime (and paint re-application) could be made, tailored to specific geographical areas.

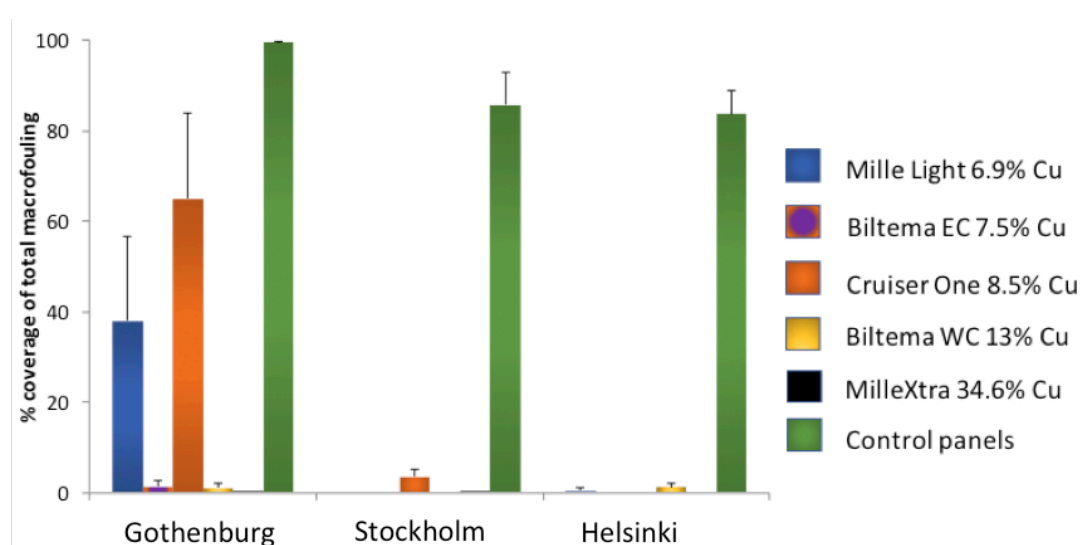
### Possibilities to reduce maintenance time and costs

The panel tests showed that several of the commercial paints were efficient during two full boating seasons, provided that the paint is gently cleaned between seasons, for example using a soft sponge and tap water. It is important that the hull is not high-pressure hosed since it is highly destructive for the paint film and its function.

These results suggest that the time and money boat owners spend on maintenance can be reduced without compromising antifouling efficacy. However, for this to work, the coated hull must be treated gently during maintenance. Instead, boat owners could

focus on re-painting damaged and exposed parts only and avoid using high-pressure hosing since it destroys the paint layer and reduce the performance of the paint during the second year.

Our tests of high-pressure hosing a number of commercial antifouling paints showed that some high copper containing paints (e.g. Mille Xtra 34.6% Cu<sub>2</sub>O) poorly withstood high-pressure hosing, meaning that they release high amounts of copper to the run-off water. Thus, it is seemingly unacceptable to allow paints that contain high amounts of copper while at the same time do not withstand high-pressure hosing well. Particularly when the low copper content paints have such excellent antifouling performance and emit copper during high-pressure hosing that is almost 100 times less in comparison to paints with high copper content (Larsson, 2016). Last but not least, the costs for water treatment of marina wash pads could be much lower if only hard paints that are designed to resist high-pressure hosing would be allowed on leisure boats.



**Figure 4.9.** Fouling coverage on panels that have been exposed during two boating seasons without re-painting in between (although new control panels were used the second year). Only slight surface coverage (<5%) was found on the paint with 7.5% copper in Gothenburg, which is a hot-spot for barnacle settlement.

## Conclusion from the panel tests

Our research demonstrates that large-scale monitoring using field panels is an excellent method to support and provide policy makers with recommendations in order to develop new strategies for sustainable antifouling practice on a legislative level. Large-scale monitoring programs are however difficult to maintain over time due to funding limitations and work intensity. Nevertheless, the use of field panels to monitor fouling is comparatively a cheap, simple and highly valuable method, which can also be applied for management at a local level. Boat clubs or individual boat owners who use biocide-free mechanical methods can, for example, determine when it is time to clean the hull by checking the settlement on a panel by their boat or placed in the marina.

The results show that commercial paints containing 7% copper oxide (with 10-25% zinc oxide) work equally well as paints containing 13-35% copper oxide (Wrange et al., *manuscript in prep.*), highlighting the overuse of copper in antifouling paints today. The excess copper serves no antifouling function but instead contributes to the pollution in marinas from maintenance work over unprotected grounds (Lagerström et al., 2016). A paint with even lower copper content (4.3% copper oxide with 10% zinc oxide) has the



same antifouling efficacy as high copper content paints (13-34.6%) and not only in the Baltic Sea Proper, but also in the Kattegat area during a full boating season (150 days) (Wrangé et al., *manuscript in prep.*). Commercial paints with low copper oxide content (7.5%) are fully efficient against fouling during two full boating seasons (2 x 150 days) without re-painting in both the Baltic Sea and in the Kattegat (Wrangé et al., *manuscript in prep.*).

Our results show that it is possible to reduce the release rates of copper in antifouling paints to meet the lower end of the ranges that we have measured for commercial paints (see above), without affecting the antifouling efficacy. It is also possible that release rates below these ranges are efficient in deterring fouling too, however this requires further evaluation. Additionally, release rates were found to be significantly affected by environmental parameters (e.g. salinity). The release rate behaviour was also found to be paint-specific, revealing the unsuitability of applying one release rate prediction model to all types of antifouling paints, regardless of difference in paint formulation. The findings highlight the need for the derivation of both condition-specific (with conditions reflecting the intended use of the product) and paint-specific release rates for more realistic environmental risk assessments. For this reason, we recommended that the XRF method be made a standardized method for evaluating antifouling paints and thereafter used to determine release rates for risk assessments.

Finally, although large improvements can be achieved by changing what antifouling paints are available on the market and how they are used, an even better option is to find ways to make boat owners move away from biocide-based antifouling paints and instead choose biocide-free methods. Furthermore, improving maintenance practices of boat hulls painted with biocidal antifouling paints would largely contribute to reducing the input of toxic antifouling compounds into the Baltic Sea. These aspects will be addressed in the following parts of this chapter.

## Biocide-free antifouling methods and marina infrastructures

### Biocide-free antifouling methods, boat tests and self-monitoring

As already described, biocide-based antifouling paints are dominant in the boating culture as the most common method to combat marine biofouling. This is for example illustrated in a questionnaire among Swedish leisure boaters revealing that approximately 80% of boat owners use toxic antifouling paints (Dahlström et al., 2014). However, there are a number of environmentally friendly, biocide-free antifouling methods available on the market.

Apart from biocide-free paints, there are also mechanical methods, i.e. paint-free techniques, which can be used to keep the boat hull free from fouling. Several of these methods are readily available on the market and already used by boat owners around the Baltic Sea. The methods have also been tested and scientifically evaluated in the BONUS CHANGE project. Table 4.10 presents different biocide-free techniques, their functioning and the suppliers or producers of the methods. There are several factors influencing how effective the different techniques are and how often they need to be applied, e.g. depending on the geographical location, the salinity in the water, temperature and fouling pressure. Other factors include the type of boat, how it is used (e.g. shorter day trips or longer cruises) and the usage frequency during the boating seasons. Hence, the table also provides information under which conditions the technique is suitable to use.



Since the market for biocide-free techniques steadily is growing with innovations and new products entering, the list of techniques (including information about suppliers, producers and costs) should be seen as a snapshot of methods commonly used by the time of writing this chapter (2017).

**Table 4.10.** *Biocide-free antifouling techniques.*

| BIOCID-FREE<br>AF TECHNIQUE  | Performance in<br>different fouling<br>pressures  | Description of<br>technique   | Supplier,<br>producers  | How to buy or<br>lease and costs   |
|--|---|---|---|--|
| <b>BRUSH WASHING<br/>STATIONS</b><br>   | Full AF <sup>11</sup> performance in all fouling pressures. The brush intervals in high fouling pressure need to be more frequent.  | Suitable for all kind of boats up to 16 m LOA. <sup>12</sup> Needs to be within a convenient distance for boaters   | Boatwasher<br><a href="http://www.boatwasher.se">www.boatwasher.se</a><br><br>Rent under<br><a href="http://drivein-boatwash.com">http://drivein-boatwash.com</a><br><br>Venepesu<br><a href="http://www.venepesu.fi">www.venepesu.fi</a> | Lease or a boat club, marina or municipality can make investment to install a boat washer.<br><br>The cost for the boat owner varies between different stations and can e.g. depend on the size of the boat and the frequency of use. Sometimes season tickets or clip card can be bought. |
| <b>HULL COVERS</b><br><br> | Full AF performance in all fouling pressures. Sometimes the hull cover does not protect the vertical part of the stern from fouling (depending on the shape). Therefore, the stern sometimes need to be cleaned with a handheld cleaning device once or twice per season (depending on fouling pressure). | Suitable for motorboats up to 10 m LOA. used for day cruising. If the boat has overnight accommodation and is used for trips, which lasts for more than two weeks, a combination of a hull cover and cleaning in a brush washing station can be an option. In general, the cover needs to be installed every year in the spring and removed and cleaned by the end of season. The cover needs to be attached to a jetty and to two poles or buoy anchors in the back. | Clean Marine<br><a href="http://www.cleanmarine.se">http://www.cleanmarine.se</a><br><br>CleanBoat<br><a href="http://www.cleanboat.se/">http://www.cleanboat.se/</a>   | Sold directly from producers to consumers.<br><br>The price for Cleanboat for a boat up to 6,5 meter is about 610 euros.   |

<sup>11</sup> Antifouling (AF).

<sup>12</sup> Length overall (LOA).

| BIOCIDE-FREE<br>AF TECHNIQUE  | Performance in<br>different fouling<br>pressures  | Description of<br>technique  | Supplier,<br>producers  | How to buy and<br>deliver/lease<br>these techniques   |
|---|---|--|---|---|
| <p><b>HULL COVER WITH<br/>BUILT IN FRICTION<br/>SCRUBBING AWAY<br/>THE FOULING</b></p>                                 | <p>Full AF performance in all fouling pressures. The hull cover does not protect the vertical part stern and most models are aimed for boats with V-shaped hulls. Therefore, the stern sometimes needs to be cleaned with a hand-held cleaning device once or twice per season (depending on fouling pressure).</p>                 | <p>Suitable for motorboats up to 7,6 m LOA. used for day cruising. If the boat has overnight accommodation and is used for trips which, lasts for more than two weeks, a combination of a hull cover and cleaning in a brush washing station can be an option. Can be kept in water all year round, however this reduces the service life of the product. The cover needs to be fixed to the jetty and to two poles or buoy anchors in the back.</p> | <p>SeaBoost Powerturf<br/><a href="http://www.seaboost.fi/products/seaboost-powerturf/?lang=en">http://www.seaboost.fi/products/seaboost-powerturf/?lang=en</a></p> | <p>Sold directly from producers to consumers and from selected retailers.</p> <p>Price for SeaBoost Powerturf varies depending on package, and can e.g. depend on the size of the boat. The producers also offer renting possibilities.</p> |
| <p><b>HAND HELD<br/>CLEANING DEVICE</b></p>  <p>Source:<br/><a href="http://www.seaboost.fi">www.seaboost.fi</a></p> | <p>Full AF performance in all fouling pressures but depends on the cleaning intervals. It is important to use it frequently enough to prevent the growing of hard shell fouling (e.g. mussels or barnacles) because if the shells are too hard, they are more difficult to clean off and the scrubbing device could be damaged.</p> | <p>The hand scrubbing device is used while the boat is in water. Suitable for smaller boats. Preferably used in combination with non-toxic paint.</p>  | <p>SeaBoost Powerbrush<br/><a href="http://www.seaboost.fi/seaboost-powerbrush-2/?lang=sv">http://www.seaboost.fi/seaboost-powerbrush-2/?lang=sv</a></p>            | <p>Sold directly from producers to consumers and from selected retailers.</p>   |

| BIOCIDE-FREE AF TECHNIQUE  | Performance in different fouling pressures   | Description of technique   | Supplier, producers  | How to buy and deliver/lease these techniques                          |
|--|--|--|--|--|
| <b>BOAT LIFTS</b><br> <p>Source:<br/><a href="http://www.sunstreamboatlifts.se">www.sunstreamboatlifts.se</a></p> | Full AF performance since the boat is not in contact with water when it is not used, avoiding any type of fouling to occur.  | Different function depending on the lift. At the moment, mechanical boat lifts are only available for motorboats and rib boats and suitable for boat owners making shorter boat trips. Larger lifts for sailing boats are on the market, but as they are expensive they are mainly offered by marinas. | Different producers and suppliers around the Baltic. Examples include Sunstreamboat lifts<br><a href="http://www.sunstreamboatlifts.se">www.sunstreamboatlifts.se</a><br>Docky<br><a href="http://www.dockymarin.se">www.dockymarin.se</a><br>A-laiturit<br><a href="http://www.a-laiturit.fi">www.a-laiturit.fi</a> | Sold directly from producers to consumers and from selected retailers. |
| <b>HARD EPOXY COATING WITH A NON-STICK SURFACE.</b><br>   | This type of coating has not sufficient AF properties in itself but should be used in combination with other biocide-free methods e.g. hull covers, brush washing stations or handheld cleaning devices. | The low-stick properties give the boat a hard surface and protection for the gelcoat which also makes it easier to clean. Suitable for small as well as larger leisure boats.  | SeaBoost Overdrive<br><a href="http://www.seaboost.fi/seaboost-coatings/">http://www.seaboost.fi/seaboost-coatings/</a>  | Sold directly from producers to consumers and from selected retailers. |
| <b>FOUL RELEASE COATING</b><br>   | Performs in marine, brackish and fresh water, even exposed to strong fouling pressure.   | The paint has a self-cleaning function. The fragile paint surface should be cleaned carefully if fouling occurs. Suitable for all boats. Removal or resealing of existing antifouling paints before use.   | <a href="http://www.hempel.com">www.hempel.com</a>   | Sold directly from retailers   |



Another option is “dry stacking” or land storage i.e. that all or most leisure boats in a marina are stored on land during the boat season, instead of keeping them in the water by the piers when they are not in use. These arrangements can be found globally, but are not common around the Baltic Sea although there are examples (e.g. Pampas marina on the Swedish east coast). Moreover, this may be a question of future infrastructure and investments for marinas, rather than for the individual boat owners.

If using mechanical cleaning devices, it is important that all biocidal antifouling paint has been removed first. Most antifouling paints are not designed for mechanical cleaning because they are too soft. If hard brushes (e.g. brush washers or handheld devices) are used on hulls with old paint layers of antifouling paints, the chemicals and biocides will be dissolved and spread in the water.

The silicone-based paints possess a self-cleaning function, which keeps the hull mostly free from fouling. However, these paints have fragile and soft surfaces. It is therefore important not to use them in combination with methods that are rough on the hull e.g. the SeaBoost Powerturf hull cover; stiff and hard handheld brushes; or cleaning the boat in a brush washing station since this will damage the coating and its function. Nevertheless, there are biocide-free hard epoxy paints on the market that are well suited to combine with, for example, a hull cover or using the brush washing station.

## Evaluation of non-toxic antifouling alternatives

During one boating season, about 15 members of Nynäshamns Motor Boat Club on the east coast of Sweden, tested different biocide-free alternative antifouling methods. The boat owners decided themselves which method to test. During the test season, the BONUS CHANGE project made several visits to the marina where the members in Nynäshamns Motor Boat Club have their boats. The boat owners participating in the test were interviewed and their boats were documented on film and with pictures. The tested methods were also discussed at a final meeting at the end of the boat season. Based on this, several important results were obtained, where both advantages and disadvantages of the different methods could be identified.

The boat owners that tested hull covers (from *CleanBoat* and *SeaBoost Powerturf*), experienced that they gave satisfactory result and would like to continue to use the hull covers next season. Depending on the shape or size of the boat, the stern was sometimes unprotected and in some cases there were some barnacles on the stern where the hull was not enough covered. Therefore, the stern may need to be cleaned with a handheld brush once or twice a year. The work to clean the hull cover from fouling after the season was not very demanding.

The municipality of Nynäshamn has installed a new and modern brush washing station in the guest harbour right next to the club’s harbour facility. This was used and evaluated by some of the boat owners. They experienced that cleaning the boat two or three times in the brush washing station was enough to keep their boats free from fouling during the entire boating season. Depending of the shape of the boat, the stern of the boat sometimes needed to be cleaned manually too, with a handheld device like a brush. Easy access to the wash station was a critical issue for the boat owners, meaning that distance and placement inside the marina was important. The price for using the brush washer was estimated to be as approximately the same as to painting (normally the boat owners pay per wash).

Using handheld cleaning device (Scrubbis) in combination with fouling release paint (silicone paint) was also tested. The method was experienced to be suitable mainly for smaller boats since it was difficult to reach the lower parts of the hull on larger boats.

### Self-monitoring of barnacle settlement

As a part of the evaluation in Nynäshamn, the boat owners also monitored barnacle settlement by using a Plexiglas panel hanging from the jetty alongside their boat. This was very effective because the boat owners were kept informed when the barnacles had settled and were given an indication when it was time to wash the boat hulls.

The instruction was to take up the panel and feel with the fingertips over the surface for traces of small newly settled barnacles. If the panel had small barnacles on the surface, the advice was to wait one or two weeks until the settlement period was over, and then clean the boat in the brush washing station or with a handheld brushing device like the Scrubbis. In the evaluation in Nynäshamn, the monitoring panels gave the boat owners an indication when to visit the brush washing station.

## On a hull cover in Råå, Helsingborg

At the far end of the jetty stands Sven Svensson. He is slightly bent over the ropes that keep his boat in a steady grip in the gale. It is already late October and dark clouds are passing over the leisure boat harbour in Råå outside of Helsingborg. Rain is in the air and when I approach, he raises his head and waves me welcome. Sven is a boat owner who has decided to stop painting with toxic antifouling paint. For good.

– Here she is, says Sven and points at the white motor boat on the navy blue hull cover. The boat is a Bella Hard Top with the length of 17 feet equipped with a Yamaha outboard engine. The boat is placed on a hull cover which is attached to the stern posts and the jetty. The hull cover is made of the same material found in the cover of Lorries. There is only one major difference; the hull cover has a built in buoyancy. That is how it works. The hull cover floats up to the surface of the water and pushes the water away to make contact with the hull. Between the hull cover and the hull there will not be enough water, oxygen or light for marine fouling organisms to settle.

– I have used the hull cover for five years now. The cover works perfectly. No barnacles or other fouling on the hull and I do not have to lie under the boat and paint with toxic smudgy antifouling paint every year, says Sven.

Sven Svensson has been a boat owner most of his life. First, when he was younger, he owned sailing boats. Now, when he is older, the sailing boats have been replaced with a motorboat. The first years as a motorboat owner he painted the boat with antifouling paint.



– Every spring I used to lay under the boat and paint with antifouling paint. It was smudgy, uncomfortable and not good for the environment either. You know, the body and especially my knees hurt when I lie under the boat now that I've passed seventy. I was about to sell the boat, but a friend of mine who introduced me to this new method, persuaded me to keep the boat and buy a hull cover instead, says Sven.

With the hull cover, owning a boat became much easier, according to Sven. The maintenance work is easy and he does not have to lie under the boat with a paintbrush in his hand anymore. The painting has, however, been replaced by another kind of maintenance work. In the fall the hull cover is much heavier because of the barnacles on the underside and the water outside Helsingborg has a relatively high fouling pressure. I ask Sven if the hull cover is hard to handle and clean.

– At the end of the season I tow the hull cover to the slipway, turn it over and clean it using a brush and high-pressure hosing. Then I fold it together into a handy package and store it in my garden. The best part is that I can stand up with the high-pressure hose and the brush when I clean the hull cover in the fall. It's a hundred times better than having to lie on your knees and your back under the boat with a paint brush in your hand and paint the hull with toxic antifouling paint, says Sven.

The dark clouds over the leisure boat harbour in Råå have passed, but the wind is still strong. The summer is definitely over and it is time to take the boat out of the water. This is actually the purpose of the visit here in the leisure boat harbour in Råå. We will inspect how well the hull cover has protected Sven's boat from fouling. The winch on the trailer makes a terrible noise, louder than the wind, and out of the water comes the white hull with the bow first. The stern dips in the water, but finally the boat makes a gentle jump out of the water and on to the trailer.

– Look here, says Sven and points at the hull, just some algae in the water line, but no barnacles. We move along the sides of the hull and there are no traces of barnacles, but we find a few high up on the stern. According to Sven, this is how it usually looks like. The hull cover gives a good protection against fouling, but the stern needs some extra attention. It needs to be cleaned with a brush once or twice per year, according to Sven. Sven cleans the hull, very skilled, with the high-pressure hose. After a few minutes the work is completed.



– The only work that remains is to drive the boat on the trailer to my garden and put some tarpaulins over her. Maybe I polish her as well. Then she will be ready for the next season, says Sven.

## On a hull cover in waters with high fouling pressure

Outside Gothenburg in one of the city's larger harbours for leisure boats called Långedrag, the Forsdahl family has their mooring place for their boat, a Ryds 548 with an outboard engine. When the boat was delivered, completely new from the factory, it had no toxic antifouling paint on the hull. This was an active decision when the boat was ordered from the manufacture. Instead of toxic antifouling paint, they bought a hull cover to keep the fouling organisms away. The first season with the hull cover has passed and the family is fully satisfied with the antifouling efficacy. Hans Forsdahl, the father in the family, tells us that he regularly during the season has checked the hull for fouling.

– I have not felt that the boat is slow or that the engine has to work extra hard. If the hull cover was not effective enough we would have noticed the effects of fouling now in the end of the summer. I have not seen any fouling when I swim underneath the boat either, says Hans.

The first season Hans left the hull completely untreated, i.e. just the plain gel coat and no extra protection.

– Next season I will paint the hull with some kind of biocide-free hard epoxy paint preferably with a non-stick surface. To have the untreated gel coat exposed is not optimal, says Hans.

In the water outside of Gothenburg, the fouling pressure is very high. Unlike the east coast of Sweden where barnacle larvae just settle two or three times per season, the west coast of Sweden has larvae in the water almost the whole summer, with highest intensities in July-August. On untreated Plexiglas panels that were deployed in the sea outside Gothenburg during the BONUS CHANGE project, the layers of barnacles can be several centimetres thick. Here, an untreated hull can form an entire ecosystem during a summer. Therefore, it is especially exciting to witness when the family Forsdahl's boat is lifted out of the water. If an untreated boat hull under these conditions is free from fouling, there will be no doubt that hull cover is a good alternative to toxic antifouling paint. When the boat is placed on the trailer we lay down on our knees to inspect the hull.

– It looks good. I am pleased with the result. Some algae in the water line and a couple of very small barnacles have managed to settle on the hull, but they probably died before they grew large, says Hans, also explaining that the efficacy of the hull cover was beyond his expectation and that he would not hesitate to recommend the method to other boat owners.

The small barnacles are very easy to remove with the fingers and Hans has an explanation for the dead barnacles on the hull.

– I did not install the hull cover until a couple of days after midsummer. Probably the barnacles settled on the hull before I installed the hull cover and later died because of the hull cover, says Hans.





## Improvement of maintenance practices and marina infrastructure

Maintenance of boats painted with toxic antifouling paint also contribute to the spread and supply of antifouling toxins in marine waters, sediments and soils in boatyards. There are several maintenance practices that boat owners engage in, when taking care of their boat. Before launching the boat in the spring, the hull is prepared for the upcoming season by scraping off loose paint flakes followed by re-painting the hull with new paint. These activities produce waste (some of which are toxic) that needs to be disposed, e.g. paint cans, brushes and paint flakes. By the end of the boating season, boat hulls are usually cleaned off with high-pressure hosing or a simple sponge and water before the boat is stored for the winter.

Most boat owners do this maintenance work themselves (hiring service companies to do maintenance work is quite expensive) meaning that there should be clear guidelines what to do and how to do maintenance work in order to minimize the spread of antifouling toxins to the surroundings. Yet, sustainable maintenance practices (i.e. undertaken in a way that not contribute to spread of toxic compounds from paints) often require certain infrastructure and equipment. The table below (Table 4.11) presents an overview of the different maintenance activities as well as the infrastructure required to do them with limited effect on the environment.

**Table 4.11.** *Improvements of marina infrastructure.*

| TARGETED ACTIVITY/<br>ISSUE            | Required infrastructure in marinas   |
|--|--|
| HULL CLEANING AND<br>IN-WATER CLEANING | <p><b>Wash area in the marina</b><br/>Construction of a clearly designated wash area with a wastewater treatment facility for the collection and filtration of wastewater, and sedimentation of particles in tanks.</p> <p><b>Only allow high-pressure hosing in the wash area</b><br/>High-pressure (hp) hosing should be restricted to the wash area with wastewater treatment facility. No permission should be given of pressure washing outside designated areas. Only boats with hard macrofouling on the hull should be hp hosed. Boats with soft fouling should be cleaned with a soft sponge and tap water.</p>   |
| SANDING AND SCRAPING<br>THE HULL       | <p><b>Designated areas for scraping and sanding</b><br/>Provision of clearly designated sealed work areas for hull scraping and sanding. If maintenance areas not are sealed, the work should be performed over tarps, drop cloths or other protective cover.</p>  |
| HULL PAINTING                          | <p><b>Designated areas for painting the hull</b><br/>Painting should occur in designated sealed work area or over an impermeable surface or over a protective tarp.</p>  |
| WASTE AND<br>COLLECTION<br>EQUIPMENT   | <p><b>Receptacles for hazardous waste and collection equipment</b><br/>Provision of adequate numbers of trash cans, dumpsters or other receptacles placed around the marina at convenient and clearly marked locations for hazardous waste<sup>13</sup> from hull maintenance.</p> <p>Provision of receptacles for dust waste<sup>3</sup> and paint particles<sup>3</sup> from sanding and scraping the hull. Also provision of receptacles for the catchment of scraped-off biofouling.</p> <p>Properly designed containers for empty paint cans and flasks/containers/bottles containing hazardous liquids.</p> <p>Provision of adequate number of dustless vacuum sanding machines and vacuum tools for scraping by the marina to the boaters in pollution prevention measures to prevent the release of contaminants produced during hull maintenance activities from reaching the soil, air and surface waters.</p> |

As mentioned, clear instructions to boaters are very important. This can be done by providing adequate signs for identifying hazardous waste and proper disposal and can be communicated by e.g. pamphlets, flyers or newsletters. It may also be included in a marina's regulation e.g. in form of Code of Conduct or berth rental contracts between the boat owner and the marina.

<sup>13</sup> Hazardous waste is paint chips (antifouling and superstructures), sand dust, ignitable paint waste, parts cleaning solvents, heavy metal containing waste like batteries, sacrificial anodes etc. Paint chips of antifouling paints should, due to their biocide content, be classified as hazardous waste. Hull scraping and sanding produce solid waste such as paint chips and dust that can contaminate air, soil, surface waters and bottom sediments and should also be regarded as hazardous waste. Liquid hazardous waste comprise antifreeze liquids like glycol, bilge water, solvents, and black and grey wastewater.

## How much can we reduce the supply of copper from leisure boats in marinas?

To demonstrate how much copper is released from leisure boats today, we present four case studies where the total release of copper from leisure boats during a boating season (May-October) has been calculated in four different marinas in the Baltic Sea-Kattegat region.

Through this, we want to illustrate that with relatively small measures, the supply of copper from leisure boat antifouling practice to the environment can be reduced substantially, thereby avoiding unnecessary harmful environmental impacts in shallow coastal areas. Therefore, we ask the questions: 1) How much copper is released from leisure boats in a marina during a boating season, and 2) How much could we reduce the copper being released in the marina, by changing our antifouling and maintenance practice?



**Figure 4.12.** Map with marinas included in the copper load calculations.

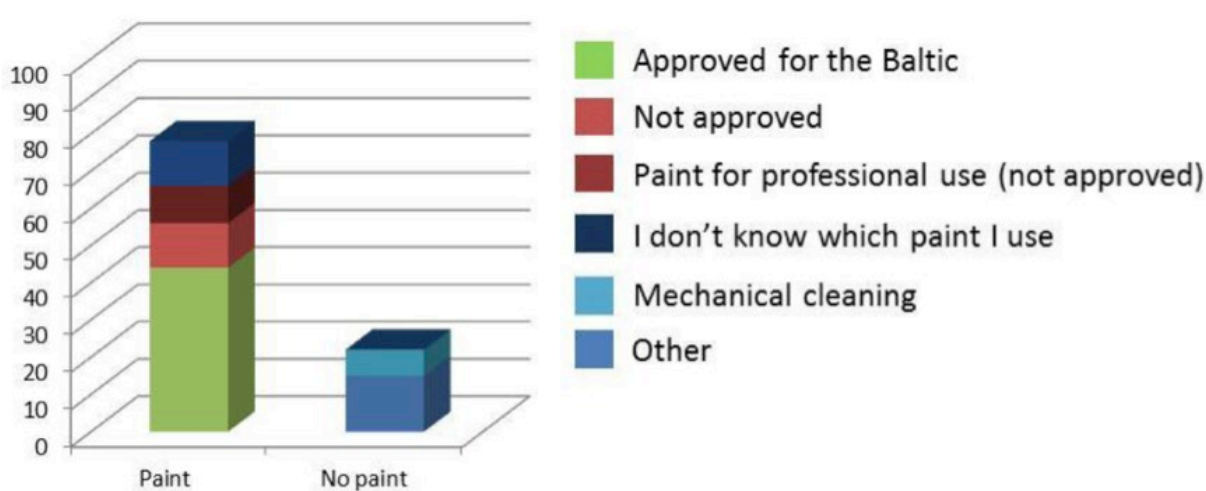
We chose to include two marinas on the Swedish west coast (Kattegat): Fiskebäck and Björlanda Kile, close to Gothenburg and two marinas on the Swedish east coast (Baltic Sea): Kalmar and Nynäshamn (Figure 4.12). The calculations are based on answers from a survey performed with Swedish boat owners in 2012 (Dahlström et al., 2014) as well as release rate data on antifouling paints that have been authorized for Swedish waters by the Swedish Chemicals Agency (KEMI). We have calculated the possible reduction of copper supply from leisure boating, by comparing the “current” scenario (based on survey results) with a “future” scenario, where boat owners have adopted more sustainable antifouling practice and boat maintenance.

### Current antifouling practices: The boat owner survey

In 2012, we conducted a comprehensive behavioural and attitudinal study of leisure boat owners in relation to antifouling products and techniques (Dahlström et al., 2014). The study examined consumer product choices, handling of antifouling paints on land and at sea, i.e. scraping of paints and cleaning of the boat hull during the season. Nearly 1,900 boat owners from 19 different marinas, from Gävle to Strömstad (in the Swedish Baltic Region and Kattegatt-Skagerrak) were asked to participate. Of these, some 35% answered the survey. Focusing on the results for the Baltic Sea in particular (Gävle to Malmö), the survey showed that the traditional copper paints still largely dominate antifouling use. Moreover, as many as 28% of the boat owners paint their boats with non-approved preparations, i.e., paints for maritime shipping use (professional paints) and paints for leisure boats, which are not approved in the Baltic Sea as based on Swedish regulations (Figure 4.13).

The survey also showed that only 18% of all boat owners along the Swedish Baltic Sea coast did use a wash pad with wastewater collection when high-pressure hosing their boats at the end of the boating season (on the Swedish west coast the number was 55%). We also found that as many as 86% of the boat owners leave paint flakes and dust on the ground after scraping, thus boatyards become heavily contaminated, as shown by soil measurements (see Chapter 3).

Furthermore, only 10% of the marinas have designated areas for scraping and facilities for taking care of paint disposals. Hence, the survey shows that there are a number of potential sources from which copper and other antifouling toxins are spread; both the type of paint used and the release rates from the hull when the boat is in water, as well as maintenance practices and how they are performed. Further details about the full survey can be found in Dahlström and co-authors (2014).



**Figure 4.13.** The graph shows the different antifouling methods used in the Baltic region from Gävle to Malmö in Sweden. Out of the boat owners using antifouling paints (78% of the total), the proportion using approved paints is 56%; the proportion of boat owners who do not know which paint they have used is 16% and the proportion of boat owners using non-approved paints is 28%.

## Estimating supply of copper from antifouling paints

In order to be able to estimate the total load of copper from leisure boats in a marina, we must know how much copper is released from the antifouling paints during a season (i.e. calculate the total amount copper from the figures of the respective the release rates given by the industry). Biocide containing antifouling paints must pass an environmental risk assessment (ERA) that is performed by the competent national authority prior to being released on the market. In an ERA of antifouling biocides, paint manufacturers must determine the release rate of the active biocides from the paint film to the water. The release rates we have use were obtained from the Swedish Chemicals Agency (KEMI).

When comparing the release rates obtained with the standardized methods (Mass Balance, MB, and Rotating Cylinder, RC, which are described previously in this chapter) with the new XRF method for measuring release rates from field panels, we can show that the correction factors which are used, result in a gross underestimation of the copper released (Lagerström et al., *in press*). Instead, release rates obtained from the standardized methods (MB and RC) *without* applying the correction factor were shown to be more consistent with the release rates derived from the XRF method. Since we do not



have XRF release rate data for all paints included in the survey results, we have therefore chosen to do our calculations of the release rates based on the non-corrected release rates of copper in seawater ( $\mu\text{g cm}^{-2} \text{ day}^{-1}$ ) for each of the paints that were reported by the boat owners.

## Antifouling practices today and in the future

For our calculations of total copper load from leisure boating in marinas, we have taken into account three aspects of boat maintenance. The first is painting of the boat hull, which is often performed every year. The second is the supply of copper from high-pressure hosing of the boat hull during uptake at the end of the season (with or without wash pad with waste treatment). Finally, we have included the supply of copper from scraping and sanding the boat hull during spring, before re-painting (with or without protection of the ground).

Two different scenarios were created in order to calculate how much copper that is released from leisure boats in a marina today, but also to estimate how much we could reduce the copper being released in the marina by changing our antifouling and maintenance practice.

In the first scenario we calculate today's copper load from antifouling maintenance in the marinas based on the results from the boat owner survey (Dahlström et al., 2014). From this, we obtained information from individual boat owners in each of the four marinas concerning the type of boat they had (including hull size), time in water (days per season), which paint (or other method) that was used to prevent fouling, paint volume used, boat usage and maintenance practice. The current antifouling practices are described in table 4.14. We assume that there is no protection of the ground during scraping or collection of wastewater from wash pads is used. The total copper released to the environment is a summary of the copper from release in water and maintenance practice.

We also calculated the copper load from antifouling maintenance in marinas in a future scenario. In this scenario, we assume that boats under 6 meter have converted to biocide-free methods whereas boats above 6 meters still used copper-based antifouling paints, but only with a maximum 4% copper oxide content and with a maximum release rate of copper of  $5 \mu\text{g cm}^{-2} \text{ day}^{-1}$  (based on panel studies described in previous section of the chapter). We assume that most people use good maintenance practices (protecting the ground and collecting all waste from cleaning and maintenance work) and that cleaning systems for wastewater treatment are 100% efficient.<sup>14</sup>

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<sup>14</sup> An evaluation of current cleaning systems for wastewater from wash pads in Sweden showed that, in many cases, these systems still were insufficient (SwAM, 2012).

**Table 4.14.** Information from the survey with boat owners in 2012 and assumptions made to calculate copper load to marinas in the two different contamination scenarios.

| Marina  | Baltic Coast (Swedish east coast) |        | Kattegat (Swedish west coast) |           |
|---|-----------------------------------|--------|-------------------------------|-----------|
|   | Nynäshamn                         | Kalmar | Fiskebäck                     | Björlanda |
| Number of berths                              | 210                               | 150    | 950                           | 2400      |
| Number of persons answering the survey        | 23                                | 40     | 55                            | 105       |
| <b>"Today Scenario (survey 2012)"</b>         |                                   |        |                               |           |
| % painting with Cu paint                      | 83                                | 65     | 98                            | 95        |
| % using non-toxic alternative                 | 17                                | 35     | 2                             | 5         |
| % cleaned on washpad (waste collection)       | 0                                 | 30     | 55                            | 63        |
| % collecting waste from scraping              | 20                                | 12     | 9                             | 30        |
| <b>"Future Scenario"</b>                      |                                   |        |                               |           |
| % painting with Cu paint (all boats >6m)      | 39                                | 57     | 64                            | 89        |
| % using non-toxic alternative (all boats <6m) | 61                                | 43     | 36                            | 11        |
| % cleaned on washpad (waste collection)       | 100                               | 100    | 100                           | 100       |
| % collecting waste from scraping              | 100                               | 100    | 100                           | 100       |

The calculations concern both the direct release of copper from the painted boat hull to the water,<sup>15</sup> as well as the release of copper resulting from maintenance sources.<sup>16</sup>

<sup>15</sup> For each boat in the four marinas, we calculated the amount of copper released to the water over a full season (150 days) based on hull area under water (cm<sup>2</sup>), copper oxide content in the paint ((w/w) % converted to µg), release rate of copper from that paint (µg cm<sup>-2</sup> day<sup>-1</sup>) and number of days in water. We then calculated an average release per boat (including all reported paint types), in each marina based on the survey, and multiplied it with the total number of berths available in the different marinas to get an estimate of the total amount of copper being released to the water during a boating season.

<sup>16</sup> To estimate the contribution of copper from maintenance work, we first calculated the copper content left on each hull after a boating season, and assumed that 5% of the paint is removed during high-pressure (HP) hosing (which is a rough estimate since paints behave differently to HP, as shown by Larsson 2016). Furthermore, we assume that 10-20% copper is removed from the hull by scraping or sanding on the paint layer during the spring maintenance (before new paint is applied). These assumptions are based on survey answers from boat owners on how much of the hull in average that they scrape per year.

## Substantial reductions of copper can be achieved

The total supply of copper being released into the environment (water and land) in our four case study marinas is shown in table 4.15. It ranges from around 30 kg per season for each of the two smaller marinas in the Baltic Sea, to between 300 and 700 kg yearly in the larger marinas Fiskebäck and Björlanda Kile on the Swedish west coast. This represents, in average, between 144 and 351 g copper per boat and season (the higher values are for the west coast marinas). When comparing the current scenario with a future scenario, we find that copper release to water can be reduced by between 51% and 75% by changing the choice of antifouling technique. In addition, by improving our maintenance practice, the total potential supply of copper can be reduced by 57% and 79% (Table 4.15).

As a comparison, if we use the same scenarios but instead use the release rates with applied correction factors (as used in authorization of products), the estimated release of copper to the water are 25-50% lower than the ones without the correction factor. However, as mentioned previously, the XRF measurements clearly show that copper release is being underestimated when applying the correction factors. The values of release rates obtained by using the XRF method are closer to the non-corrected values obtained from the standard methods used for estimating release rates (CEPE Mass balance and Rotating cylinder methods).

**Table 4.15.** Results from calculations of copper supply to different marinas, for two different scenarios; the “today scenario” and the “future scenario”. The copper supply includes both copper released into the water from painted hull surfaces and from maintenance work.

| TODAY SCENARIO   |           |        |           |           |
|--|-----------|--------|-----------|-----------|
| Cu load from different sources/season                                      | Nynäshamn | Kalmar | Fiskebäck | Björlanda |
| Cu release to water based on release rates without correction factor (kg)  | 30        | 33     | 333       | 672       |
| High pressure hosing contribution (assuming that 5% of Cu is removed) (kg) | 1.0       | 0.7    | 7.5       | 10        |
| Cu released from maintenance scraping (kg)                                 | 3.3       | 3.3    | 61        | 78        |
| TOTAL Copper load (kg)   | 35        | 37     | 402       | 760       |
| FUTURE SCENARIO  |           |        |           |           |
| Cu load from different sources/season                                      | Nynäshamn | Kalmar | Fiskebäck | Björlanda |
| Cu release to water based on release rates without correction factor (kg)  | 10        | 16     | 83        | 294       |
| High pressure hosing contribution (assuming that 5% of Cu is removed) (kg) | 0         | 0      | 0         | 0         |
| Cu released from maintenance scraping (kg)                                 | 0         | 0      | 0         | 0         |
| TOTAL Copper load (kg)   | 10        | 16     | 83        | 294       |
| Reduction (%) of copper load (release to water only)                       | 65        | 51     | 75        | 56        |
| Potential TOTAL reduction (%) (including maintenance)                      | 70        | 57     | 79        | 61        |

## Further aspects of copper supply to the marine environment from antifouling paints

With our study, we show that we can achieve a considerable reduction in copper being released to shallow coastal waters by changing our antifouling and maintenance practices, using technologies that are available today. Based on the studied marinas and our scenarios, the reduction has been estimated to between 57% and 79%. The main aim of this calculation was to highlight the possible positive impact that simple changes in antifouling practice can have. The estimation of the copper supply is based on a number of assumptions, as described above. Therefore, it is important not to focus too much on the exact numbers. Rather it is important to focus on the relative change that these two scenarios highlight, which indeed is substantial.

There are several other aspects to consider when discussing the total supply of copper to marinas from antifouling paints and hull maintenance work. Firstly, since many boats have been and are painted each year, it results in a build-up of multiple paint layers of toxic biocides, which are released from the hull during maintenance work, thus contributing to the overall copper contamination in marina waters. Based on our calculations of how much paint is used each year per boat, and the estimated release of copper over a season, we find that an average of 52% (+/-23% SD) of the copper remains on the boat hull after a full boat season. This is the average for all boats and commercial paint types used in the four marinas.

In addition, within the BONUS CHANGE project we have found that a large number of leisure boats carry the prohibited and very toxic organotin compounds in underlying paint layers, which may also be released during hull maintenance work. The optimal solution in the future would therefore be to remove all old paint layers before applying a non-toxic hard paint with low-stick properties or a low copper containing paint.

When discussing release of copper, it is important to consider the efficiency of cleaning systems connected to wash pads. Based on an evaluation from Sweden, they have been shown to be insufficient in many places (SwAM, 2012). The water that is released from wash pads after waste treatment in Swedish marinas is currently allowed to contain a maximum of 0.8 mg/L of copper, according to the Swedish Agency for Marine and Water Management (SwAM, 2012). This untreated wastewater will also contribute to the total supply of copper in the current scenario.

The most beneficial future scenario for the marine environment would be using only paints with low copper content combined with a minimum release rate that still prevents fouling. It would also be desirable that this paint is fully depleted of its copper content during a boat season. It would minimize the copper left on the boat hull when the boat is taken up and thus, minimize the copper being released during maintenance work. However, this requires that old toxic paint layers are removed from the hull or fully sealed with a sealer paint that blocks release of toxic biocides from underlying paint layers (although the problem still remains in the latter case).

Furthermore, we have not taken into account that copper from paint flakes that end up on the ground during maintenance work, do not necessarily end up in the sea directly. Instead copper may remain in the paint flakes over time or bind to soil particles and remain a source of contamination. Improvement of maintenance practice could easily minimize this source of pollution.

Finally, it is important to remember that the marinas already today are in many cases heavily polluted, both on land and in the sediments inside the marina (Lagerström et al., 2016; Bighiu et al., 2017) and copper bound to sediment particles can be re-suspended from the sediments or washed off from land, adding to the total load of copper present in the marina. In addition, it is not only copper that has been used in antifouling paints, resulting in a cocktail of different chemicals and toxic substances being present in the marinas, which can affect marine life, separately or in combination with other substances.

## **CHANGE towards more sustainable antifouling practices**

In this chapter, we have presented results from field tests using panels to study the natural fouling pressure and evaluated performance of copper-based antifouling paints throughout the Baltic Sea region. We can show that low copper-based paints are highly effective against fouling throughout the entire Baltic Sea. We have also presented results emphasising the importance of considering environmental conditions (salinity) as well as the total paint composition and expected lifetime when discussing release rates of antifouling paints. Our findings also highlight several issues concerning current methods used to estimate release rates for risk assessment and authorisation and we present a new promising alternative tool (XRF) for future assessments.

We have also described biocide-free alternative antifouling methods and their very good performance in preventing fouling in the Baltic Sea. Especially in areas where the fouling pressure is relatively low, all mechanical methods are highly efficient and should be promoted strongly. Moreover, we have suggested improvements of marina infrastructures that can facilitate for boat owners to choose more sustainable antifouling and maintenance practices. Finally, we have showed that by changing our choice of antifouling method, i.e. reducing the use of toxic paints and investing in more environmentally friendly alternatives, we can substantially reduce the load of copper being emitted to the coastal environments from leisure boating.

Overall, we have shown that by changing the initial choices of paint, promoting non-biocidal methods in combination with local monitoring, and improving maintenance practice as well as infrastructure, we can drastically reduce the overall supply of copper into the coastal areas of the Baltic Sea region.

Our findings, together with the research presented in the previous chapter (3), describe a broad range of results and arguments against continued use of toxic antifouling paints on leisure boats. However, many people are already aware of that these paints are not good for the environment – and still toxic paints remain the most common method used to avoid fouling. Therefore, we set out to study how antifouling practice and consumption behaviour are connected. This will be presented in the next chapter.



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## Chapter 5

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### Understanding antifouling practice and consumption patterns

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Sustainable consumption research focuses on the ways consumers make decisions about what products to buy. Consumer researchers examine the attitude-behaviour gap, demonstrating that even those consumers who report having a positive attitude toward sustainability are actually no more likely to make a sustainable product choice than other consumers (Vermeir & Verbeke, 2006; Gupta & Ogden, 2009). They study the impact of sharing and anti-consumption as means of restricting the negative effects of overconsumption (McDonagh & Prothero, 2014). Researchers also focus on the dispositional end of the product life-cycle, examining consumer activity with respect to recycling and up-cycling<sup>17</sup>, burning disposed products for power production and disposal of used products in landfills (Lastovicka & Fernandez, 2005; Brosius et al., 2013). However little research has focused on the ways consumers use products, and how product use affects environmental impacts, including toxic emissions.

In this chapter we describe several aspects of consumption of antifouling products. We first explore how use and the maintenance of leisure boats results in different environmental impacts. More specifically, with a Life Cycle Assessment (LCA) we compare various products and methods developed for boat maintenance used in the marine environment and examine whether the choice of products could lead to goal conflicts between the releases of biocides in toxic paints and greenhouse gas emissions. Next, we examine the reasons behind leisure boaters' current maintenance practices with respect to consumer culture, specifically the influences of infrastructure and regulatory actions. Finally, we investigate the ways the marketplace impacts of an overarching paradigm of paint advertising and market norms.

### Do choices of maintenance and antifouling methods lead to goal conflict between biocide and greenhouse gas emissions?

Research has shown how consumer product use, particularly in lighting and textiles, can have profound impacts on the environment (De Saxce et al., 2012; Yu et al., 2016; Iraldo et al., 2017). This is also the case for leisure boating. In our research, we demonstrate how the various ways boat owners maintain and use their boats result in a myriad of environmental impacts.

The widespread use of antifouling paints containing copper and zinc results in increased toxicity as these compounds leak from the paints and are emitted to the marine ecosystem. They can also enter the sea through dry land when old paint is scraped or washed from boat hulls during boat maintenance work. Interrelating factors affect the environmental impact of leisure boat use and maintenance. These factors include the type of paint used, how often the entire boat is painted or whether only parts of the boat hull are painted, how many layers of paint are applied, disposal of paint scrapings and used paint tins, and how long the boat is submersed. Similarly, non-toxic hull treatment

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<sup>17</sup> Creative reuse where by-products are transformed into new materials or products.

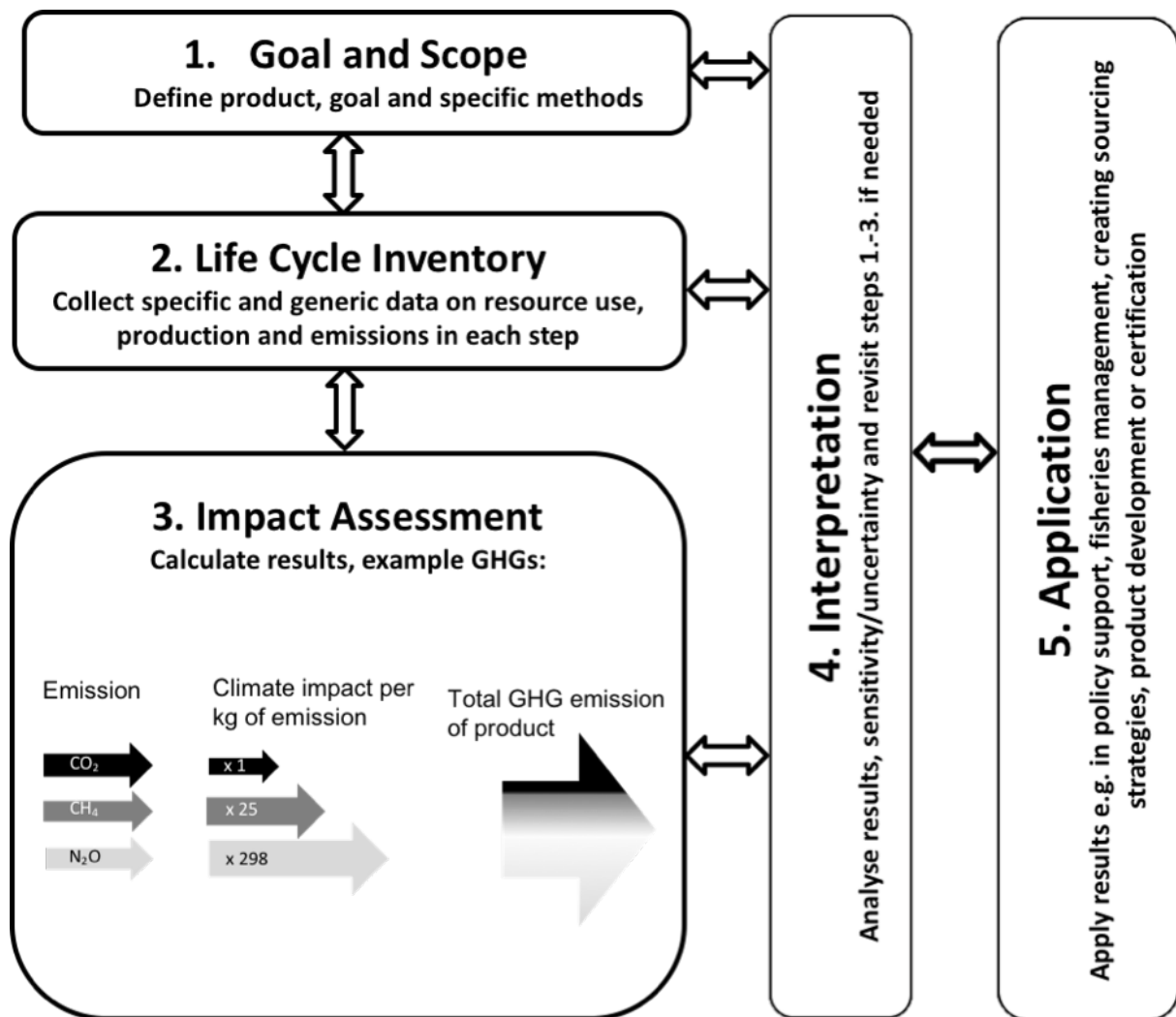
methods, e.g. boat washers and sponges, include number of factors that influence the overall environmental impact of leisure boating. These include the distance between the boat's homeport and the boat washer contributing to fuel combustion used for propulsion combustion which leads to air and water emissions, and the service life of the antifouling products. Thus, environmental impacts in the context of antifouling practices and maintenance vary and also depend on the antifouling method applied. Therefore, boating and how we use and practice antifouling is analysed from a broad system perspective including the different environmental impacts it contributes to during the whole life cycle.

## Environmental impacts and systems analysis

Systems analysis is a scientific framework that characterizes environmental impacts of production systems in a holistic way with the overall goal of identifying improvement options. This analytical method idea includes all parts of the system that are potentially influenced by a change. Systems analysis often employs Life Cycle Assessment (LCA), a widely used and established method for quantitative environmental assessment of products and processes. The method is standardized by the International Organisation for Standardisation, ISO (2006a, b) which ensures a reliable analysis of good quality when performed according to the standard. LCA is used to quantify a broad suite of environmental impacts of products throughout their life cycle (Baumann & Tillman, 2004), from extraction of raw materials up to the end of life of the product. The undertaking of a LCA is divided into five steps, with iterative loops (Figure 5.1).

In the first step, Goal and Scope, the goal of the study and the product to be studied are defined. The scope refers to the point in the product supply chain the study will follow. LCA goals include comparing the environmental impacts of products fulfilling the same function or comparing current production with some type of modelled change of a technical, regulatory or biological nature. Different goals lead to different study designs. For example, when modelling the impact of a planned change, only the steps of the supply chain affected by that change need to be included. When comparing products, only steps differing between the assessed supply chains need to be included. If the goal, on the other hand, is to identify activities that contribute disproportionately to overall impacts, an analysis of the entire supply chain of the product need to be included. A number of other important specific method choices also need to be made, such as which types of environmental impact to assess, e.g. acidification, toxicity, eutrophication or global warming.





**Figure 5.1.** The five steps of Life Cycle Assessment.

After completing Goal and Scope decisions, the next step is data collection or *Life Cycle Inventory* (LCI). The LCI involves collection, quantification and comparing data on material and energy use (inputs) and generation of waste, emissions and produced products (outputs) for each step in the supply chain. The data can originate from various sources. The LCI is a critical step of LCA performance since the reproducibility, consistency and precision of the data collected determines the quality of results.

The third step follows, the *Impact Assessment*. All quantified flows are summarized over the entire supply chain. Resources used and emissions generated are grouped according to the types of resulting environmental impacts. LCA can include a wide range of environmental impact categories (for a recent review see Hauschild et al., 2013)

The fourth step of performing a LCA consists of *Analysing and Interpreting* results, including sensitivity and uncertainty analyses to see how robust results are to data variability, important assumptions or methodological choices. Depending on these analytical outcomes, earlier steps of the analysis may need to be revisited (e.g., more data may need to be collected) before a LCA model is finalized.

The fifth and last step is specific to LCA, the *Application of Results*. LCA results are often applied for improving environmental impacts which can be achieved for example

through product development, changed sourcing strategies, or consumers' use of products. LCA results may also be used to enable more informed choices for retailers and consumers. Moreover, it can be used to inform policy-making (ISO, 2006a, b) by evaluate the broad environmental impacts of alternative policies, prior to, during or after policy implementation. The use of LCA has become a regular practice to justify the implementation of environmentally-oriented decisions at a cooperative and/or political level in the US and in Europe (Finnveden et al., 2009).

## Antifouling as a Life Cycle Assessment (LCA) case study

Recreational boating is a popular activity in nearly all Baltic Sea countries. For example, large boat parks can be found in Germany and Denmark with 500,000 and 250,000 recreational boats respectively (Eklund et al., 2013; ICOMIA, 2016). The aggregate environmental impact of these large fleets of leisure boats is considerable, in particular locally. We therefore designed a case study to learn more about how boat owner behaviour affects the environment. By applying the LCA, it was possible to examine new innovative, non-toxic antifouling methods compared to the conventional antifouling paints.

In this study, we base the primary assumptions on Swedish boating information since it is both extensive and readily available. In Sweden, the majority of boats are kept at a private dock or on land during the boating season. 90% of boat owners manage their own boat maintenance. Yet, only 16 % of owners have access to a facility that collects runoffs from washing at their winter storage, thus one can assume that most toxic paint residues end up on the ground (The Swedish Transport Agency, 2016) and eventually run into the catchment and ultimately the sea. Of Swedish recreational boat owners, 80% used their boat sometime during year, with an average of 16 days during the 5-month long boating season (The Swedish Transport Agency, 2016).

We designed different scenarios reflecting the variety of ways Swedish leisure boats are used and maintained. Four different scenarios using antifouling paint were created: a worst-case and a best-case scenario resulting in the highest and lowest toxic environmental impacts, respectively. The worst-case scenario included paint with high copper concentration, cleaning without wastewater collection and the average amount of paint used by Swedish boaters (Dahlström et al., 2014). The best-case scenario included paint with low copper concentration, cleaning with wastewater collection and less paint used (less frequently and only a part of the hull painted plus paint diluted). Two additional innovative biocide-free antifouling scenarios were created. One included no painting and scraping but maintenance with a brush washer, situated either at the home marina or further away. The other included use of a hull cover for antifouling protection of the boat hull.

These four different antifouling and maintenance scenarios were compared with respect to the environmental impact of *one boating season without fouling* (so called functional unit for comparison). All scenarios were analysed for two types of environmental impacts: aquatic eco-toxicity and climate change. The emissions of copper and zinc or other substances affecting aquatic organisms were grouped into the impact category "Aquatic Eco-toxicity" which is calculated by weighing together a number of aspects e.g. effects and exposure of the substance. All Greenhouse gas emissions (GHGs) were grouped into the impact category "Climate Change" based on their relative radiation forcing index, as defined by the UN Intergovernmental Panel on Climate Change (IPCC, 2014) and measured in kilograms of carbon dioxide equivalents (Figure 5.1).

The analytical method allows us to, in our analysis, include not only how much copper that is released from paint (and direct effects of that), but also how many *other* toxic emissions that are released e.g. from petrol combustion and the resulting toxicity in comparison to that of copper. In addition, changes in antifouling practices can lead to other types of environmental impact such as eutrophication or GHGs. Therefore, the analytical method can also illustrate potential trade-offs; if changed antifouling practices, e.g. from paints to biocide-free techniques, may imply shifting environmentally impacts such as increasing energy use while reducing toxic emissions or vice versa.

Results showed that there was a significant difference in the potential of aquatic eco-toxicity between the worst-case and best-case scenarios for antifouling paint as antifouling method: Using paint with low copper concentration and collecting and treating all paint wastewater as hazardous waste, greatly reduced aquatic toxic emissions. However, compared to the biocide-free antifouling methods, the copper-based paint method still contributed more to aquatic eco-toxicity regardless of copper concentration in the paint or maintenance practices. The effect on climate change was more or less equal between the scenarios except for the scenario with a brush washer located further away from the home marina, which had higher impact due to emissions from additional fuel consumption. The scenario where hull cover was used as antifouling technique had low environmental impact, both on aquatic eco-toxicity and climate change. The factors that contributed most to eco-toxicity in the paint scenarios were the emissions of copper and zinc leaking from the painted boat hulls. For the scenarios of biocide-free antifouling methods, it was the emissions from combustion of fossil fuels.

The case study demonstrates that different ways of keeping a boat hull free from fouling differ significantly in terms of environmental impacts. The toxic content of the paint was heavily correlated to toxic environmental impacts. In this aspect, the non-toxic treatments performed well, i.e. they did not lead to any other toxic emissions that outbalanced the reduced emissions of not having the boat painted with copper and zinc containing antifouling paints. Having said this, we did however identify trade-off situations. For the brush washer, it was important that it was located as close to the home port as possible, otherwise, greenhouse gas emissions from fuel production and combustion reached higher levels of climate change impact than for the other methods.

## **Boater antifouling practice is influenced by infrastructures and leisure boat cultures**

Adoption and use of biocide-free antifouling products as well as other sustainable boat maintenance practices depend on existing marina infrastructures, such as the presence of boat washers or wash-down pads. Practices are also related to the boat culture, the taken for granted way of maintaining leisure boats and enjoying time at sea. Both the infrastructure (structural systems) and boat cultures (cultural systems) are crucial for the success of changing antifouling consumption into more sustainable practices. Boat cultures are deeply embedded in the values and traditions of any given sub-culture within boating cultures, which in turn are influenced by the culture of each country. The following section accounts for the role of infrastructure in shaping sustainable consumption practices of boat maintenance. This is followed by a multicultural analysis of maintenance practices uncovering the similarities and differences among boat owners in different cultural contexts of Germany, Sweden and Finland.

We use a specific type of qualitative methodology - practice theory (Shove et al., 2012) - to examine boat cultures and marina infrastructures of boat maintenance on the Baltic Sea. Using practice theory basically means that we apply a very broad understanding of what boat maintenance means and based on this, we classify boating practices along material, competence and meaning dimensions. The *material* dimension includes not only the boat hull as such, but also all the material objects needed to go boating such as equipment, clothing and gear. It also include objects needed for boat maintenance, such as wash-down pads, paints, boat washers, boat lifts and hull covers. In addition, boating and maintenance work requires money and time spent on these activities. The *meaning* of 'boating' differs between individual boat owners, but is commonly connected to "fun", "enjoyment" and "holiday". Nevertheless, boating could also be part of a nature experience or be a way to spend time with friends and family. Similarly, the meanings of boat maintenance vary from exhausting hard work, to nice hobby experience and social get together in the marina. The *competence*, of boating and boat maintenance is the practical knowledge that one has as a leisure boat owner to be able to go boating and to maintain the boat in a proper manner.

The material, meaning and competence dimensions of boating and boat maintenance are interconnected and depend on each other. For example, if one mainly enjoy boating for the experience of nature (meaning) one might not care so much about speed, so this will influence the choice of boat (material) and the competence needed for navigation. If one, on the other hand, enjoys high speed boating, the choice would be a fast boat requiring other navigation skills.

The material, meaning and competence dimensions of boating and boat maintenance clearly shows that we can change unsustainable antifouling practices, primarily by changing either material elements as infrastructures or the meaning of boating.

## Changing infrastructures, changing antifouling practices

In order to understand current antifouling practices, we wanted to study them in the context where they mostly take place. Therefore, our study took place mainly at marinas. We collected data in marinas in Germany (Kiel); Sweden (Gothenburg and Stockholm) and Finland (Helsinki). These sites were chosen to represent different features found in marinas in the Baltic Sea. The data encompasses ethnographic observation with extensive field observations including notes and photographs from the marinas, and interviews with boat owners as well as harbourmasters.

Of specific interest was to see how antifouling practices are influenced by marina infrastructure. In our research, the concept of 'infrastructure' includes the material and physical infrastructure in marinas, but also forms of 'institutional infrastructure' such as economic incentives, legislation and regulations or Code of Conduct, established on national or local levels or adopted in a specific marina (Buhr, 2003; Torrisi, 2009). The inclusion of rules and regulation in combination with the physical infrastructure is something that has been overlooked within consumption research. However, it is highly relevant and important since regulations steer the boaters' choice of antifouling method and how to use the infrastructure. For example, a marina can require boat owners to wash their boats on designated areas with water treatment and if this rule is violated, a sanction or fine is issued.



The biocide-free, non-toxic antifouling methods are fairly new entrants to the market and as such are not in wide use. Nevertheless, these alternatives are innovative and effective: a qualitative evaluation within the BONUS CHANGE project shows that the majority of the boat owners that have tested biocide-free antifouling methods accept them and find them effective (see Chapter 4). Consumers consequently need to be convinced that these methods can work as well or better than toxic paints. Yet, they don't work equally well on all hull designs, and can thus represent a greater workload for the boat owner. It is still to be seen whether they prove to be more cost effective than the traditional paint option. In addition, many of the biocide-free antifouling techniques and sustainable maintenance practices also require other type of supporting infrastructure at the marina (see Chapter 4).

Our research found that maintenance options are determined in great part by the mechanical and technical arrangements and installations present in each marina. In order for a boat owner to engage in more sustainable antifouling practices, certain infrastructural conditions are required. At the same time, non-existing infrastructure can hinder boat owners from maintaining their boat in a way that is more sustainable. Important infrastructure can for example include availability of alternative biocide-free antifouling options (e.g. boat washers) and infrastructural solutions that support sustainable maintenance of leisure boats painted with biocide-based antifouling paints (e.g. provision of recycling and waste collection, wash pads with wastewater treatment, protective foil that hinders scrape-offs to contaminant the soil).

The provision and use of the infrastructure has strong linkages to rules, regulations and codes present in the marina, which also are connected sanctions. Findings from BONUS CHANGE research shows that this type of 'institutional infrastructure' is central since it sets the frames for material infrastructures and steer maintenance behaviour of boat owners to make them use the material infrastructure that is provided. Regulations or codes for boat maintenance in marinas, combined with regular supervision connected to sanctions and fines have in this respect a positive effect on the environment by limiting the spread of toxic compounds.

Our research also demonstrates differences among national legislation regarding boat maintenance. National regulations are important as they set the framework for the type of material infrastructure that is required in a marina for waste and recycling, scraping, painting or cleaning the boat hull. Furthermore, both technical infrastructure and the related rules and regulations must be mutually supportive, i.e. established, organised and supervised in a way that constrains consumer behaviours toward more environmentally sustainable practices. Thus, boat maintenance is not just a matter of individual choices, but also highly dependent on marina infrastructure which can either support or hinder more sustainable consumption practices.

### Does antifouling practices depend on cultural differences?

Differences in antifouling practices were revealed in the respective boating cultural contexts. The sustainability of each of the antifouling practices has in large part to do with the presence of and compliance with the prevailing rules and regulations and how these are supported and enforced by local authorities. Boat owners in Germany, for example, are expected to follow quite strict rules of use and disposal. Separate bins are provided in the marinas to encourage proper disposal of toxic antifouling waste. Moreover, adequate enforcement of rules is ensured as sanctions and fines are levied

on boaters who are caught breaking the rules. Fines were for failing to put tarps or other protective foil under lifted boats to catch old paint flakes and scrape-offs during hull scraping prior to the application of fresh paint.

Results from the study show that some Swedish boaters follow their own understanding of how to get the best antifouling results and some use less paint than recommended by manufacturers. However, other Swedish boaters purchase and use higher copper content toxic paint formulas than necessary for their location, in direct defiance of a ban of these paints in their local area. In Sweden, paints are authorised explicitly for the east coast *or* the west coast, based on the toxicity necessary for effective antifouling. In high water salinities, like the Swedish west coast, the fouling attachment to boat hulls is much higher than on the Swedish east coast. Because of that, the boaters on the Swedish west coast are allowed to have higher levels of toxins in their paints. Yet, it is possible for all boaters to buy the more toxic paint and east coast boaters also use this paint, defying the ban.

In Finland we found very little awareness of toxic antifouling paint use and resulting negative environmental effects on marine life, even though there is common knowledge that antifouling paints are toxic. Much like the Swedish context, there is little infrastructure in marinas and harbours to support more sustainable antifouling practices. Finnish boaters consider visible litter, septic tank contents and industrial effluence to be the main cause of ‘fouling’ the sea; antifouling paint is not recognized as a source of environmental degradation.

Fouling can slow down boats and ships considerably. The main reason boaters use antifouling paint is therefore to keep barnacles and other marine organisms off the hull to ensure smooth sailing, through better manoeuvrability. The use of antifouling paint to keep the boat hull clear from barnacles means less drag in motion, and therefore less fuel use and GHGs. Because of this trade-off, boat owners who use even the most toxic paints to keep boat hulls free of bio-fouling see themselves as proactive protectors of the environment.

## Market and advertising influence antifouling practices

The previous section illustrates that the current antifouling practices, where painting with biocidal paints dominates, is to a large extent influenced by infrastructures and leisure boat cultures. In this section, we illustrate how advertising and the supply of products shapes unsustainable buying decisions in the context of antifouling.

The companies that sell antifouling paints or mechanical antifouling products and services work with marketing tools such as advertising and branding. This marketing communication is intended to attract customers and influence their behaviour. The following section shows how the consumption of antifouling products and practices linked to leisure boats is intimately connected to desired leisure boat lifestyles, which are not only influenced by associated meanings mediated by advertising (Markkula & Mosiander, 2012; Moisander et al., 2010) but also through the supply and exchange possibilities of antifouling products.

The description and discussion of the interdependence between marketing practices and consumption in the case of the Swedish market for antifouling products is based on different sources of data. The data collection of advertising of antifouling products consists of two parts. First, we analysed advertisements for antifouling products in the

Swedish boating magazines such as *Båtliv*, *Båtnytt*, *Praktiskt båtägande* and *På Kryss* published between 2010 -2017. We then conducted observations in main antifouling retailers in the Swedish cities of Gothenburg, Stockholm and Borås. We were especially attentive to how products were advertised in stores.

The supply of antifouling products was studied in the main retailers in Sweden; Jula, Biltema and Seasea. The supply of antifouling products at different locations around the Swedish coastline was of particular interest as some antifouling paints only are approved for use on the Swedish west coast, and copper-based paints are not approved for use north of Örskär, i.e. in the Bothnian Sea and Bothnian Bay (east coast). Furthermore, we were interested in the offerings of environmentally harming products compared to environmentally friendly products provided by the retailers to the boaters. In-store observations were augmented with analysis of retailers' websites.

Advertising and similar forms of visual product presentation were viewed and analysed for both implicit and explicit messages. Advertising consists of carriers of meanings, which are communicated between both a sender and an intended receiver (Sunderland & Denny, 2007), and have been explored in this study. Thus, we followed a long tradition of anthropological consumer research (Otnes & Scott, 1996; Sherry, 1987; Sunderland & Denny, 2007) in this cultural analysis of advertising.

### How are antifouling products advertised?

What does it mean to protect a leisure boat from fouling? What does antifouling mean for leisure boaters? As these questions indicate, this study was designed to uncover the meanings of antifouling for leisure boaters. The analysis of advertising and supply of antifouling products evolve around meanings of time efficiency and not spending too much money (economization). Using copper-based antifouling paints make time- and money-efficient antifouling possible. For example, the antifouling paint Micron Superior announces: "*Finally, Europe's leading antifouling paint has reached Sweden! You get a lot of paint for your money, one coat of paint is enough to keep fouling away for the entire season*". Yachting Aqualine paint for propellers and underwater areas is promoted with the slogan: "*At last clean gear all season*".

Antifouling efficiency is intimately connected to the use of copper in antifouling paints. "*Antifouling paints with the highest copper content on the market*" introduces the reader to advertising of Hempel paints. The wording of this slogan tells the reader that the more copper the better in antifouling paints. Names of antifouling paints as "*Fouling Copper*" or "*Seasea Antifouling Copper Plus*" clearly make connotations between antifouling paints and the use of copper. Copper is promoted as a necessary ingredient in antifouling practice.

Meanings of leisure boat antifouling products are linguistically and materially constituted (Markkula & Moisander, 2012). The wording, images and connotations used in advertisements for paints suggest efficiency as the critical dimension of antifouling practice and copper-based paints are provided to enable leisure boat owners' efficient antifouling products. The normalization and naturalization of copper-based antifouling paint takes place as meanings of toxicity and marine conservation are absent in marketing discourse. The ample supply of copper-based antifouling paints in Sweden further strengthens the assumption or the "truth" that antifouling practice equals use of copper (Sunderland & Denny, 2007), what we refer to as "the paint paradigm".

The problem with these advertising slogans is that the efficiency of copper is not communicated in relation to where along the Swedish coast the paint is approved for use. For example the Seajet 031, paint approved for the west coast only, is advertised under the slogan: “*Best antifouling paint in test with extremely good properties (prestanda)*”. The antifouling paints are advertised in leisure boat magazines distributed among boat owners all over Sweden. As this printed media does not allow for targeted advertising, west coast approved paints promotional texts reach east coast leisure boaters. Likewise, antifouling paints approved only for west coast use, are supplied by retailers all over Sweden. All retailers of antifouling paints on the east coast that were investigated stored paints non-approved for use in the waters along the east coast. Hence, advertising and supply of paints approved for the west coast target leisure boat owners on the east coast with the message that copper-based antifouling equals efficiency and convenience. Even though paint producers are required to clearly indicate on the product for which coast it is approved, retailers are not required to present criteria for approval in advertising nor in in-store visual presentation (Swedish Chemicals Agency, 2014, personal communication). Nor does the regulatory framework refrain retailers from selling antifouling paints approved for the west coast in east coast retail locations. It is highly probable that antifouling paint advertising and supply shape leisure boat owners’ choice of antifouling products towards copper-based paint as the connotations between use of copper-based paint and efficiency is predominant in promotional messages.

Finally, there is little advertising on alternative antifouling products as environmentally friendly paints (copper free). For example, no advertising of biocide-free paint was found in leisure boat magazines from the spring of 2014. Since 2015, there is little advertising for biocide-free paints, such as the silicone paint from Hempel, but compared to the advertising of biocidal paints it is very sparse.

### What is the supply of antifouling products in stores?

Visits at different retailers in Sweden have shown that the offering and variety of toxic antifouling paints is much bigger than the environmentally friendly alternative methods like manual scrubbing devices (e.g. scrubbis) or hull covers. This excessive supply of biocide containing paints has a big influence on the buying decision of boaters, further giving the impression that a biocide containing paint is “the best” antifouling method as there is a wide range of paints offered. Also, the actual space reserved for environmentally friendly products is very small in comparison to the huge space for copper-based antifouling paints. Moreover, there is hardly any in-store advertising for the environmentally friendly alternatives.

The fact that there are less eco-friendly alternatives offered is also highly connected to the size of the products. Environmentally friendly mechanical methods (like a boat lift or hull cover) are very large. This makes it very difficult for the retailers to present them in their stores as the presentation would take up a lot of floor space compared to the paint cans. It has led to the common practice where the majority of mechanical methods with few exceptions are either sold at boat fairs or online.

The supply of environmentally friendly methods varies a lot in terms of the boat type; there is a much bigger range of mechanical methods for motor boats than for sailing boats. For example, the keels on sailing boats precludes them from using boat lifts or hull covers.



Our study has shown that there are environmentally friendly alternative services for boaters, like the boat washer. However, this service is not available for boaters in a boat supply store. Boaters can use the service of the boat wash either in a marina or in a designated washing station. The problem with this mechanical method is the local availability. For example, boat washers are much more available on the Swedish east coast than on the Swedish west coast, where there are only two, i.e. in Stenungsund and at Smögen. This limited access means for example that a sail boat owner from Gothenburg would spend about two hours to the nearest boat washer, which is not feasible. The fouling pressure on the Swedish west coast means that these boaters need to use the boat washer 2-4 times a season. Combining the costs of travel time and frequency makes this environmentally friendly alternative not very attractive for boaters on the Swedish west coast, and as shown earlier there is also a trade-off connected to the transportation to a boat washer.

## **Reducing environmental impacts of boating by changing consumption patterns**

The different case studies demonstrate how the way towards a less toxic marine environment of the Baltic Sea is fraught with difficulties. As LCA analysis demonstrated, the use of different antifouling methods and maintenance practices can lead to more or less toxic emissions to the environment. Toxic antifouling paints contribute more to toxic environmental impacts compared to biocide-free antifouling techniques. Yet, changing antifouling practices to biocide-free techniques (brush washer and hull cover) does not lead to any other toxic emissions that outbalance the positive effects (reduced emissions) of not having the boat painted with copper and zinc containing antifouling paints. It is important that brush washers are located as close as possible to the homeport, otherwise it will increase GHGs that lead to a higher climate change impact than for the other methods studied.

This chapter provides extensive and important insights to understand what influence and shape sustainable consumption choices of boat owners. Sustainable leisure boat maintenance is highly influenced by marina infrastructure. Findings suggest that the provision of marina infrastructure, supported by rules and regulations to ensure boaters and marinas to act according to the rules, could help achieve a change in currently dominating unsustainable boat maintenance practices related to antifouling and antifouling paints. Consumption and antifouling practices also differs among cultural and national contexts. Finally, consumption of antifouling products is influenced by boating culture communicated through advertisement and supply in the market, where our study illustrates how copper paints dominate supply and are marketed as highly efficient, contributing to the prevailing paradigm of antifouling paints.

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## Chapter 6

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### Regulatory options and alternative governance structures towards less toxic antifouling practices

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The legislation related to antifouling paints and practices addresses a range of different actors and has varying legal implications on different regulatory levels. This chapter identifies and discusses different regulatory options which can be taken with the aim to minimise the use of toxic paints on leisure boats in the Baltic Sea. These options include both measures that authorities and other relevant actors can take *within the existing regulation*. It also includes *possible regulatory changes* for governments to consider. The regulatory options are divided into three categories concerning: 1) environmental quality regulation, 2) regulation of biocide antifouling paints and 3) regulation of the activities of boat owners and marinas. Furthermore, some alternative governance approaches are presented. We especially focus on the legal framework and possibilities for applying the discussed measures, as well as the interplay between public and private regulation.

### Regulatory perspectives, levels and targeted actors

Regulating antifouling paints can take its point of departure in different regulatory settings. First of all, a distinction can be drawn between *public law* and *private law arrangements*. The public law arrangements are the responsibility of authorities at international, EU, national and local level. The private law arrangements rely on private parties, e.g. private marinas or boat clubs. In this section, we mainly focus on public law.

A large number of public (environmental) laws address antifouling paints from *different regulatory perspectives*.<sup>18</sup> One first perspective is the environmental quality perspective, setting relevant environmental objectives and quality standards for e.g. water quality. It also includes identifying and implementing relevant measures to achieve these objectives and standards, e.g. to reduce the presence of toxic or harmful substances in the aquatic environment. Another regulatory perspective is the *product perspective*. It focuses on the marketing, availability and use of antifouling paints. A third regulatory perspective focuses on different *polluting activities*, e.g. the activities of boat owners or marinas when handling antifouling paints, painted boats or contaminated sediments. Finally, supervision and enforcement are important cross-cutting issues for all these perspectives.

It becomes clear that there are different regulatory options for addressing the adverse effects of antifouling paints used today. This also means that there is a wide range of actors – from the boat owner to different authorities – that should be taken into account when we consider how to regulate antifouling paints and practices. Regulation also often serves multiple purposes. For example, product regulation is to a high extent subject to EU legislation with the purpose to ensure not only environmental protection, but also the functioning of the internal market within the EU. That counts for the Biocidal Products Regulation (BPR) too, which regulates biocidal antifouling paints.

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<sup>18</sup> For more details on regulatory perspectives and national legislation in Denmark, Finland and Sweden, see Kymenvaara et.al. (2017).

Environmental quality regulation is also, to some extent, subject to EU legislation with the purpose to ensure a minimum environmental quality<sup>19</sup> e.g. defined by thresholds for polluting substances, which must not be exceeded. For the aquatic environment, this is laid out in the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD). However, national authorities play an important role when implementing the environmental quality legislation into national laws and regulations. The regulation of different polluting activities is to a large extent determined at national level, although some EU legislation also exists. Furthermore, local authorities often play an important role for local regulations as well as having supervising and enforcing responsibilities, i.e. controlling that regulations are complied with.

The simplified figure below (Figure 6.1) displays the different regulatory *levels*, and what they foremost regulate. The legal framework and some of the regulatory options for enhancing the protection of the Baltic Sea are discussed in the following sections.

|                  | Environmental quality  | Polluting products  | Polluting activities   |
|------------------|--|---|--|
| European Law     | Environmental objectives and quality standards                           | Authorization of biocidal substances<br>Prohibition of organotin compounds (TBT) on ships |  |
| National Law     | Environmental objectives and quality standards<br>Programmes of measures | Authorization of biocidal paints and their use  | Restrictions on antifouling activities like painting, scraping etc.<br>Waste management regulation |
| Local Regulation |  |   | Restrictions on antifouling activities like painting, scraping etc.<br>Waste management regulation |

**Figure 6.1.** Levels and main subjects of public law regulations.

## How can environmental quality regulation be used?

The Water Framework Directive (Directive 2000/60/EC) (WFD) and the Marine Strategy Framework Directive (Directive 2008/56 EC) (MSFD) establish the legal framework for regulation of ecological and chemical water quality in large parts of the Baltic Sea. To what extent this framework can be used to address toxin spread from antifouling paints depends, however, on the national implementation, which we will see below.

<sup>19</sup>The requirements set by EU environmental quality regulation are minimum requirements in the sense that Member States are obliged to ensure that the addressed environment has at least the quality defined by EU regulation. Since it is minimum requirements, Member States may take measures to ensure a better quality.



The Directive on Environmental Quality Standards (Directive 2008/105/EC) (EQSD), also known as the Priority Substances Directive concerns pollution in surface water. It identifies a number of substances that pose a substantial risk to the aquatic environment. The directive also set environmental quality standards (EQS) for these substances (i.e. limits or thresholds on the concentration of these substances in water, or biota, which must not be exceeded if good chemical status is to be met). The polluting substances are categorized into “priority substances” and “hazardous priority substances”, the latter being of particular concern. This classification of substances becomes highly important because antifouling substances classified as hazardous or priority substances at EU-level no longer are approved for use in antifouling paints. The only antifouling substance that is identified as a hazardous priority substance is TBT, while diuron and cybutryne (Irgarol) remain classified as priority substances.<sup>20</sup> The presently authorised antifouling substances used today, including copper and zinc, are not classified at EU level in the EQSD. However, it is possible for national authorities to address these substances in the national implementation of the WFD. For example, Sweden has since 2016 established national general limit values for copper and zinc, and also decided on general measures to avoid exceeding these limits in the new programme of measures (PoM, see below).

Moreover, the environmental quality regulations imply setting relevant environmental objectives. The environmental objectives are legally binding on national authorities, e.g. when they are deciding upon permit applications for polluting activities. If national authorities have set environmental objectives or limit values for antifouling substances, it could also affect authorisation process of new antifouling paints. Nevertheless, most antifouling activities such as boat maintenance work or running a marina do not require permits. In order to fulfil the objectives of the directives, Member States need to take measures also to avoid pollution also from non-permit activities.

Not only setting relevant objectives or standards are important, but also to identify relevant measures to address pollution arising from antifouling paints. The environmental quality regulation obliges Member States to identify and implement relevant measures in order to achieve the environmental objectives and good environmental status of their marine areas, for example in the form of marine strategies or programme of measures (PoMs) as part of River Basin Management Plans (RBMPs). Thus, PoMs and marine strategies provide opportunities for Member States to identify relevant measures to address pollution related to the use of antifouling paints e.g. the establishment of wash-down pads in marinas. In general, however, it will rely on the initiative of the relevant authorities to what extent such measures are being implemented or not, as the RBMPs and marine strategies are not directly binding upon private parties.

## How can regulation of antifouling paints be used?

### Introduction to the regulation of biocide antifouling paints

The production, sale and use of antifouling paints is to a large extent regulated at EU-level. Antifouling paints are chemical products, containing chemical substances. In the EU, chemical products are generally regulated in the REACH Regulation (Regulation 1907/2006/EC). However, most antifouling paints are biocidal products,

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<sup>20</sup> TBT, diuron and cybutryne have previously been allowed for use in antifouling paints. These substances are today not authorised and can thus not be used.

meaning that they are chemical products containing an active ingredient (biocide) intended to control any harmful organisms. These products are specifically regulated by the Biocidal Products Regulation (BPR, Regulation 528/2012/EU). In addition, organotin substances, like TBT, are prohibited on all boats (Regulation 782/2003/EC), e.g., no organotin compounds are allowed to be present on any boat hull.

Biocidal antifouling paints need to be approved (authorised) before they can be sold within EU. The BPR establishes these rules for authorisation of active substances (the biocide) at EU-level and authorisation of biocidal products, e.g. antifouling paints, at national level.<sup>21</sup> Even if the product authorisation is done at national level, the regulation specifies how the product authorisation shall be performed.

There is currently a transition period (with transitional rules) before the BPR comes fully into force. Because of this, there is not yet any absolute requirement for Member States to adopt an authorisation procedure according to the BPR. This means that the BPR has not yet been fully applied nor interpreted by the Court of Justice of the European Union (CJ) that has the final say on the interpretation of European law. It is not possible to predict with certainty how the Court will interpret the provisions of the BPR. Therefore, it is not possible to say exactly how large a Member State's leeway will be when it comes to e.g. authorising products and possibility to restrict the availability of antifouling paints.<sup>22</sup> Based on the following discussion, it seems however clear that the Member States will be given some flexibility and discretion (margin of appreciation). Nevertheless, as the main purpose behind the BPR is to harmonise the legislation on biocide products, it is likely that the Member States' leeway will be rather limited.

## Grounds for refused or limited authorisation

In this section, we identify and discuss some of the major grounds for Member States to either refuse authorisation or to grant limited authorisations for antifouling paints.

The Baltic Sea with its brackish water is a particularly sensitive environment and is also classified by the International Maritime Organization (IMO) as a Particular Sensitive Sea Area (PSSA) since 2005 (IMO). This means that there is a need to consider local environmental circumstances when authorizing products, in order to protect the Baltic Sea.

Moreover, important scientific findings produced by the BONUS CHANGE project could further support refused or limited authorisation. For example, findings from the project show that several biocide-free antifouling methods work very well in the Baltic Sea, as well as many of the biocide paints authorised for use in the Baltic Sea have much higher copper content and copper leaching rates than are necessary for antifouling performance, i.e. to deter fouling organisms (see Chapter 4).

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<sup>21</sup> BPR Art. 42. Antifouling paints are specified as product type (PT) 21.

<sup>22</sup> Moreover, the technical guidance documents provided by the European Chemicals Agency ECHA, intended to explain how the risk assessment and product evaluation is to be performed, were not completed at the time of writing this chapter. This makes it even more difficult to make predictions on the exact interpretation of the rules regarding product authorisation.

## Consideration of local environmental circumstances

To start with, authorisation of a biocidal antifouling product is to be grounded on a risk assessment (considering both health and environmental aspects) of *the planned use of a product* according to the BPR (see Annex VI, sections 13-14 and 37-38 of the BPR). This means that Member States will be able to consider local environmental circumstances when they authorise antifouling paints. Since the Baltic Sea is a sensitive environment with a relatively low fouling pressure, it is possible to argue that using a biocidal antifouling paint on a boat that mainly navigates in the Baltic Sea is a quite different use, as compared painting a boat that mainly navigate marine waters such as the North Sea where the fouling pressure is much higher. This means that a biocidal paint planned to be used in the Baltic Sea may not be authorised, even if the same paint is fully acceptable in other marine waters like the North Sea. Consequently, the risk assessment based on the planned use could possibly provide basis for a national leeway concerning product authorisation because Member States will be able to consider local environmental circumstances.

Member States like Sweden and Denmark, with coastlines facing both the saline seawater of Skagerrak and the North Sea as well as brackish waters of the Baltic Sea, should consider the different coastlines in the authorisation process. Some paints may hence only be possible to authorise for use along the coasts facing the saline seawater. Such geographically differentiated authorisation will be possible as an authorisation may be conditioned (see Art. 22.1 BPR). Conditioned authorisations are already in place in Sweden, where three geographical areas along the Swedish coastline have been distinguished with differentiated authorisation of antifouling paints. Such differentiation should be possible to maintain under the BPR.

## Consideration of excessive toxicity

The environmental risk assessment shall evaluate if the product has any *unacceptable effects* on the environment (see Art. 19.1.b, subparagraph iv of the BPR). A product may therefore pass the environmental risk assessment even if it has harmful effects on the environment, as long as these effects are not unacceptable. The efficacy test, which is also a part of the authorisation process for antifouling paints, will be passed as long as the product deters fouling satisfactorily in the environment where it is intended to be used. What is clear is that these two tests do not consider if the product is more potent than needed and consideration of unnecessarily high toxicity is not included.<sup>23</sup> However, every decision in a product authorisation procedure shall be based on an integrated conclusion, where all separate tests performed are weighted against each other (see Annex VI, paragraph 78, of the BPR). It is not clearly expressed if this integrated conclusion shall include consideration of unnecessarily high toxicity. Still, one of the principal aims of the BPR is to ensure a high level of protection for human and animal health and for the environment (see Art. 1 BPR). It is furthermore expressed that the use of biocides should be limited to the necessary minimum (Art. 17.5 and paragraph 38 BPR,) and the objective to reach a more sustainable use of biocides is expressed (Art. 18 BPR). The European Commission has moreover pointed out that the product authorisation and conditions given to authorisations can be tools for minimising the

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<sup>23</sup> Art. 19.1.b. BPR, see also Annex VI para. 51-52, 77. The efficacy test is further described in ECHA (2017).

risks connected to the use of biocides and through this, promote a more sustainable use (COM, 2016). Based on this, it should not be excluded that the integrated conclusion can consider the unnecessarily high toxicity of antifouling paints, as mentioned above.

## Consideration of available biocide-free alternatives

Another issue concerns to what extent it will be possible to consider the need for using a biocidal antifouling paint, in relation to the availability of non-biocidal antifouling techniques. Could for example the availability of biocide-free antifouling options be used as an argument for not authorising or restricting the approval of biocidal antifouling paints?

According to the BPR, a comparative assessment shall be performed for biocidal products (Art. 23 BPR). Article 10 BPR states however that the comparative assessment explicitly concerns products that contain active substances which have been declared ‘candidates for substitution’. It means that it is not obligatory to assess products based on other active substances and so far, there is only one active substance approved for antifouling products that is considered a candidate for substitution.<sup>24</sup>

A restrictive interpretation of this regulation of Article 23 BPR implies that a comparative assessment *should only* be performed regarding products that contain candidates for substitution, and that such an assessment therefore is not possible regarding e.g. any copper-based paints. The statement in paragraph 15 of the preamble to the BPR says that “In the course of granting or renewing the authorisation of a biocidal product that contains an active substance that is a candidate for substitution, *it should be possible* to compare the biocidal product with other authorised biocidal products, non-chemical means of control and prevention methods” (own emphasis). This statement supports the interpretation that the comparative assessment is only intended regarding products that contain ‘candidates for substitution’. As a consequence, the availability of biocide-free options does not seem to be a legitimate argument for restricting the approval of biocide paints based on copper or any other active substance which have not been declared as ‘candidates for substitution’. Another interpretation is that the integrated conclusion, where arguments for and against authorisation are weighted against each other (see more under “Consideration of excessive toxicity” above) also enables a comparative assessment. This interpretation can be supported by the aim of the BPR to provide a high level of protection for the environment and to reach a more sustainable use of biocides. However, the wording of the BPR rather supports the restrictive interpretation.

## Consideration of Environmental Quality Standards

The availability of biocidal paints could also be restricted with specific reference to Environmental Quality Standards (EQSs). The BPR states that a biocidal product may not be authorised if its use would undermine the achievement of aims set in the Water Framework Directive (WFD), the Priority Substances Directive or the Marine Strategy Framework Directive (MSFD) (Annex VI paragraph 67 BPR). This indicates, for example, that if a boat mainly navigates on waters where there is a set limit for copper content for the water to reach good environmental status under the WFD, and the EQS for that

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<sup>24</sup> The only active substance approved for antifouling products that is considered a candidate for substitution is Medetomidine (Regulation 2015/1731/EU).

water is set to good environmental status, a paint containing copper should not be authorised for use on that boat if the limit is exceeded. Since limit values for e.g. copper and zinc are established by Member States, there is a possibility to bring up a more restrictive national product authorisation approach by recognising low limit values of these substances. The Swedish competent authority has established different limit values for copper and zinc for the Baltic Sea waters (0.87 µg/l for copper and 1.1 µg/l for zinc) compared to the Swedish west coast and the waters of Skagerrak, Kattegat and the Sound (2.6 µg/l for copper and 3.4 µg/l for zinc).<sup>25</sup> If the limit values for the Baltic Sea would be exceeded, paints containing these metals should not be authorised for use in the Baltic Sea. A problem here is that the copper and zinc content in waters may vary locally and measurements are also performed for smaller water bodies. It means that the limits may be exceeded in some parts of the Baltic Sea but not in other parts. On the other hand, biocidal antifouling paints are today authorised for use in rather large areas, e.g. the Swedish west coast or the Swedish Baltic Sea coast south of the Bothnian Sea. If products are to be restricted with reference to EQSs, these geographical designations must be made compatible. It can possibly be done through separate authorisation conditions for every water body, or through evaluation of water bodies in groups. This could however present some problems. For example, many leisure boats may be used in larger areas and it could be considered unreasonable to authorise a paint for use in one or a smaller group of water bodies where the limit is not exceeded but at the same time refuse authorisation for use of that same paint in adjacent water bodies where the limits are exceeded. Nevertheless, we can conclude that Member State may influence the conditions for product authorisation by setting low limit values for copper and zinc in their coastal waters. Exactly how such limit values can impact on product authorisation is yet uncertain, but exceeded EQS for biocidal substances is one argument for restricting the use of antifouling paints containing such substances which have to be weighted towards other arguments in the authorisation process.

## Imposing conditions for an authorisation

The BPR provide possibilities to impose different conditions for authorisation. This implies that e.g. an antifouling paint can be sold only if certain requirement(s) are fulfilled. But could this also mean that biocidal antifouling paints can be authorised with geographical restrictions on their use, i.e. not allowed to be used in the Baltic Sea? The guidance documents under the Biocidal Products Directive<sup>26</sup> did list some examples of conditions and restrictions (risk management measures) that can be part of an authorisation.<sup>27</sup> Geographical restrictions are not explicitly mentioned in the lists but the lists are also non-exhaustive. Moreover, and as we already have discussed, the product shall be evaluated and authorised based on planned use, meaning that geographical restrictions are possible.

The lists in the guidance document explicitly mention improved product formulation as possible conditions, i.e. lowered concentration of active substance or exchanging a

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<sup>25</sup> Expressed in bioavailable values (SwAM, 2013:180).

<sup>26</sup> The BPD guidance documents of the Biocidal Products Directive (BPD, 98/8/EC) are applicable until the issuance of guidance under the BPR. Note that this guidance will be replaced by ECHA with a new Biocidal Products Directive (BPD) guidance <https://echa.europa.eu/guidance-documents/guidance-on-biocides-legislation>.

<sup>27</sup> Pages 23-28, 30f, 38, 74 of the BPD guidance.



substance for a less hazardous one. Based on this, it should also be possible to e.g. grant authorisation on the condition that the concentration of copper, or the leaching rate, is reduced. A prerequisite for imposing all requirements and restrictions is that they are scientifically justified.

A major problem that has been identified by the BONUS CHANGE project is that many boats on the Swedish east coast, the Baltic Sea, are painted with paints authorised to use only on the west coast of Sweden. It may partly depend on the availability of west coast paints in stores at the east coast. An important question is therefore if it would be possible to restrict, not only where a paint is allowed to be used, but also *where a paint can be sold*. Restrictions on how the product can be sold, i.e. limited container size and warnings, instructions and labels on the container, are mentioned as acceptable conditions in the guidance document for product authorisation.<sup>28</sup> Furthermore, the active substance included in the biocidal product can be authorised with conditions, for example that the products that contain that particular substance must be provided together with protective gloves.<sup>29</sup> These issues support that products can be authorised with various conditions on sales arrangements. However, to put conditions (i.e. restrictions) on where the products can be sold would limit the market access for these products and therefore interfere with EU regulations on functioning of the internal market and counteract one of the principal purposes behind the BPR. Therefore, it remains uncertain if it would be acceptable to impose conditions on where the product is sold (e.g. west coast paint could only be sold in stores on the west coast).

## How can a Member State refuse or limit authorisation through mutual recognition?

When an applicant has applied for authorisation of a product in one Member State, or when authorisation has already been granted in that Member State (the reference Member State), it is possible to apply for mutual recognition in other Member States (the Member States concerned) i.e. that the product should be approved also in these other Member States (Arts. 32-36 BPR).<sup>30</sup> The main rule is that a Member State shall authorise the product under the same terms and conditions that the product is authorised in the reference Member State (Art 32.2 BPR). However, a 'Member State concerned' has some possibilities to refuse or limit an authorisation. Such exception must be justified on the grounds of e.g. protection of the environment or that the target organisms are not present in harmful quantities. The 'Member State concerned' must present a thorough description of the grounds for the exception to the applicant. If the 'Member State concerned' do not manage to reach an agreement on the exception with the applicant within 60 days, the 'Member State concerned' must inform the European Commission, which will then decide on whether the exception can be accepted or not. The Commission must make its decision within 90 days from being notified by the 'Member State concerned' (Art. 37 BPR).

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<sup>28</sup> Pages 23- 28, 30f, 38, 74 of the BPD guidance.

<sup>29</sup> See e.g. Commission Implementing Regulation 2016/1088/EU; Commission Implementing Regulation 2016/1090/EU; Commission Implementing Regulation 2016/1089/EU.

<sup>30</sup> Indeed, a granted authorisation in one Member State excludes a new national authorisation procedure in another Member State. The only option for the applicant in such case is thus to apply for mutual recognition (Art 29.4 BPR).

Under the mutual recognition procedure, the ‘Member State concerned’ has to show that an exception, i.e. non-authorisation or limited authorisation of the product, is justified. This is based on assessments which are comparable to the ordinary national authorisation procedure, where the risk assessment has to show that authorisation is justified (see above). However, it seems to be more difficult for Member States to refuse authorisation through mutual recognition (mainly regulated by Art. 37 BPR) than under the ordinary national authorisation procedure (which takes its point of departure in Art. 19 BPR). This is also in line with the purpose of the mutual recognition procedure, which is to facilitate market access (see the preamble to the BPR, paragraph 3). Furthermore, the ‘Member State concerned’ has a very short time frame to produce the argumentation for the exception. Moreover, as applicants may apply for (primary) authorisation in any Member State, an applicant may choose a state with less rigorous authorisation approach and subsequently apply for mutual recognition in other Member States with a more restrictive approach. The competent authorities in the Baltic Sea Member States must therefore be prepared to present thorough scientific justification for exceptions of mutual recognition within the specified short time frame in order to successfully restrict the use of the most hazardous products in the Baltic Sea.

## How can regulation of the activities of boat owners and marinas be used?

### Regulating activities or their environmental impact?

A boat painted with antifouling paint causes leaching of antifouling biocides such as copper when it is in contact with water. Except this, there are several other activities related to boating that potentially lead to release of polluting biocides from antifouling paints. Concerning the boat owners, these activities mainly concerns hull maintenance, such as painting, sanding, scraping and high-pressure hosing of the boat hull. The relevant activities regarding marinas mainly relate to whether the marina provides the infrastructure needed for boat owners to perform antifouling practices with a minimum negative impact on the environment. Such infrastructure may consist of e.g. wash-down pads with water treatment and proper waste management facilities (see Chapter 4).

The antifouling activities and their environmental consequences are mainly regulated at national or local level, targeting either the activity directly (e.g. explicit prohibitions of certain activities), or the consequences such as the environmental impact (e.g. prohibition to cause pollution or liability for clean-up of contaminated sediments). Both types of regulations are used in Sweden, Finland and Denmark where the activities of boat owners and marinas are regulated mainly through general environmental protection regulations. In Sweden, there are for example general rules of consideration which imposes requirements not to cause any damage to the environment and to handle waste and wastewater properly. In Denmark, there are general waste regulations. Local regulations also exist in some areas, e.g. harbour regulations in Denmark and municipal regulations in Finland, laying down more detailed requirements on some issues.

Regulation that targets environmental impacts has the advantage that it addresses all possible activities that boat owners engage in, and is therefore not easy to evade. In the case of Sweden, there is a general requirement for boat owners to conduct all activities (e.g. hull maintenance) in a way that minimise the discharge of polluting substances from antifouling paints to the environment. This is based on the general rules of consideration, included in the Environmental Code. The requirement is not dependent

on the specific activity. It means that an activity only is illegal if the impact on the environment is not *insignificant* in the individual case. The consequence of this is that a specific action must actually have a negative impact on the environment, in order for a municipality to enforce the boat owner's obligations. One option that could potentially enhance the municipalities' possibilities to enforce the obligations of individual boat owners may be to establish complementary requirements directed at the actual activities, e.g. an explicit requirement to always use a protective foil on the ground when sanding and scraping the boat. A system which targets the actual actions, irrespective of the impact on the environment, can be found in Germany and to some extent also in the local regulations in Finland and Denmark.

The requirements for marinas can also be regulated through targeting either activities or environmental impacts. If activities are addressed, it could consist of explicit requirements on marinas to e.g. establish wash-down pads with water treatment and provide adequate equipment for minimising the discharge of polluting substances resulting from boat owners' antifouling practices. However, such measures would not be necessary to require if biocide-free antifouling techniques are used for all boats in the marina or when the number of boats at the marina is very limited, as the impact on the environment would be very small.

So addressing the environmental impact of a marina's activities can be a bit more flexible compared to direct regulations of the activities. The flexibility implies for example that there are possibilities to impose requirements for the right measure at the right place under the right circumstances. However, it puts a large responsibility on the authorities responsible for supervision and enforcement, as they have to define what causes too much harm to the environment and what does not.

Rules that target both the activities directly and their environmental consequences, may have both advantages and disadvantages. Examples from both Sweden, Denmark and Finland show that the existing regulation establishes a high level of protection for the environment, which may be fully adequate if enforced. A problem, however, seems to be that the regulation is not sufficiently controlled and enforced.

## Imposing a permit requirement for marinas

The enforcement of marinas' responsibilities could be improved within the existing regulatory framework through increased efforts from the authorities that are responsible to ensure that the regulations are complied with. And there are powerful instruments available to better enforce the existing rules. An example from Sweden is that the responsible authority (a municipality) can issue an injunction at a marina to take certain measures if the activity contributes to exceeding the limit values established for an EQS, or otherwise cause harmful effects on the environment. An injunction may also be imposed under penalty of a fine.<sup>31</sup> If such enforcement instruments were used by authorities to a higher degree than they presently are, it would put pressure on marinas and boat clubs to take measures for reducing the negative environmental impact from antifouling practices.

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<sup>31</sup> For Swedish court cases regarding injunctions on marinas, see e.g. MÖD 2006:28 and Land and Environment Court of Appeal, case number M 11499-16.

Another, even more powerful instrument aiming to increase the supervision and enforcement responsibility of marinas and boat clubs, would be to impose a permit requirement for certain activities. This would oblige the responsible authority to consider EQS legislation and eventual limit values for antifouling substances before granting permission for the certain activity. If the activity can be expected to add to any exceeded limit values, permission should be refused. Hence, in every place where the copper or zinc limit values are exceeded, a marina should have to require that all maintenance work is conducted in a way that does not release any paint residues into the environment.

A permit requirement could also lead to requirements on marinas to take certain measures as a condition for a permit to be granted. Such measures could include e.g. establishment of wash-down pads. Since requirements of such measures would not be necessary if no biocidal antifouling paints are used in the marina, marinas and boat clubs may even be inclined to promote or require that boat owners choose biocide-free antifouling techniques, or in other ways govern the choices of boat owners so that the actual source of pollution is reduced.

### Targeting antifouling practices by regulating waste

Paint scrape-offs and other residual waste and materials from maintaining and cleaning of hulls must be collected due to the high concentration of hazardous substances, and must be treated in accordance with the national rules for hazardous waste. This includes, for example, the transportation and disposal of the waste by authorised companies. The municipalities are often the relevant authorities for waste management. In most municipalities, chemical waste like dust and scrapings from leisure boats will have to be delivered by the boat owner or the marina at municipal waste facilities.

The field studies conducted within the BONUS CHANGE project, however, show that these types of wastes are often not handled properly. One identified reason for this is lacking waste reception infrastructures. Where such infrastructures exist, more boat owners tend to handle their waste properly. One option for better waste management could be to require marinas to establish reception facilities for this type of waste. A similar requirement on marinas exists in the Port Reception Facilities Directive (Directive 2000/59/EC), which handles ship-generated waste. However, the term ship-generated waste as defined in the directive does not include scrapings, paint residues, fouling materials or wastewater from high-pressure hosing of boat hulls.<sup>32</sup>

Another option could be to require facilities for reception of paint containers, paint residues and scrapings in a permit requirement for marinas. Such reception facilities would not necessarily be more advanced than the facilities that are required at present. Therefore, this requirement could be imposed without putting any significantly larger burden on marinas. Again, these facilities would not be needed if no boaters in the marina use biocide containing antifouling paints. The requirement could therefore work as an incentive for marinas to encourage boat owners to use biocide-free antifouling options, e.g. in Code of Conduct or require the same in berth-place rental contracts.

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<sup>32</sup> What is included in the term is defined through MARPOL 73/78; Annex 1 regulation 1, Annex IV regulation 1, Annex 5 regulation 1.

## Regulating antifouling practices through Code of Conduct, tenancy contracts and marina regulations

Requirements targeting the antifouling activities of boat owners and marinas may not only be established through public law, but also through private law arrangements. Concerning boat owners' activities, private-law arrangements include for example Code of Conduct at boat clubs and marinas or berth rental contracts between the boat owner and the marina. Policies established by national or regional boat owner associations, as well as land tenancy contracts between the land owner (usually a municipality) and the marina could possibly target both the activities of marinas and boat owners.

There are some examples of private law arrangements in e.g. Sweden, Denmark and Finland. The supervision and enforcement of the requirements established through such arrangements can be more effective than the public supervision and enforcement of public law requirements. Important is however that the private law requirements are associated with appropriate sanctions, e.g. fines, expulsion from the boat club or marina or losing the right to a berth (see Chapter 5).

Private law arrangements as a regulatory option mainly concern how public law can create incentives for the involved actors to establish the above discussed instruments. One way to achieve this could be through improved enforcement of liability for contaminated land and sediments towards both land owners and marinas. As concluded by Kymenvaara and co-authors (Kymenvaara et al., 2017), the potentially high costs for handling clean-up of contaminated soil and sediments may function as an incentive for land owners to include clauses that transfer liability for contamination to the boat club or marina in land tenancy contracts. These actors would then also be incentivised to establish requirements on the individual boat owners in order to avoid contamination. Another option would be to increase supervision and enforcement of the marinas' responsibilities in general, as well as possibly imposing a permit requirement for marinas as discussed in the section above.

## Supervision and enforcement

Several authorities at national, regional and local level are involved in supervising and enforcing the regulation related to antifouling. Furthermore, there are many different actors to supervise, including paint manufacturers, retailers, harbours and marinas and not least individual boat owners. Supervising and enforcing the regulation is therefore a complex and resource-demanding issue, in particular regarding individual boat owners. These responsibilities therefore must be distributed to the authorities with the best possibilities to successfully fulfil the task. Local authorities may not have the sufficient resources, and national authorities may be too far away. Nevertheless, it seems that inspections campaigns can be carried out with some success, e.g. campaigns by the Danish Environmental Protection Agency controlling what paints are used by boaters.

However, there seems to be a general shortfall regarding supervision and enforcement. It could therefore be considered if marinas, boat clubs and boat owner associations can play a larger role in this area. These actors could function as complementary supervisors of public law requirements, e.g. harbour regulations. They could also develop and supervise their own regulations in e.g. Code of Conduct or berth rental contracts. To support the development of such requirements, guidance can be provided by the relevant authorities, while regulatory incentives, such as potential liability for clean up or remediation of contaminated sites, could also be used or reinforced.



## Alternative governance approaches

We have now presented several possible measures for authorities to take within the existing regulatory framework in order to reduce the pollution caused by antifouling of leisure boats e.g. by using the room for manoeuvre within the legislation or by improving supervision and enforcement. Some options for legislators regarding minor changes to the existing regulation has also been discussed. However, these steps may not be sufficient to reduce the pollution from antifouling paints. Alternative governance approaches could therefore be needed, complementing the existing ones. This can include new regulatory instruments which can function in synergy with the present regulation. An example given below is a tax on biocide paints. Besides regulatory instruments, non-regulatory approaches could also be used, including private law arrangements as mentioned above. Another option could be eco-labelling as shortly introduced below.

### Is tax on biocide paints an option?

The results from the BONUS CHANGE research show that there are several available biocide-free antifouling methods that work very well in the Baltic Sea. The project has also shown that boaters' awareness and consideration of the negative environmental impact caused by biocidal paints is not enough for them to choose biocide-free methods. For such choices to be made, there must be a match between several different factors, such as available infrastructures, the boaters' life-style, willingness to spend time on maintenance and the cost. Even if the cost is just one of many factors influencing the boaters' consumption decision, adjusting the cost for biocide paints by imposing a tax might be the little nudge needed for some boaters to instead choose a biocide-free method. The legal possibilities and difficulties to implement such a tax is discussed in this section.

Imposing a tax on biocidal paints to encourage boat owners to choose biocide-free antifouling techniques may be acceptable from an EU-law perspective. That is, as long as the tax is designed to meet a number of requirements defined in the Treaty of the Functioning of the European Union (TFEU). First of all, the tax must be charged as part of the internal tax system in the Member State. Otherwise, it will be perceived as a charge with equivalent effect to a customs duty, which is not allowed. Furthermore, the tax must not be discriminatory between imported and domestic products. Another requirement is that differentiated fiscal treatment of different biocide paints must be grounded on "objectives which are themselves compatible with the requirements of the Treaty and its secondary legislation",<sup>33</sup> such as environmental protection, which is recognised as a legitimate ground for tax differentiation.<sup>34</sup> A tax also must comply with the EU rules on state aid (Art 107 TFEU).

If all the requirements above on how the tax is constructed are met, it would be possible to impose a tax on biocide paints. However, the issue of designing the tax in a suitable way still remains. A tax would not result in neither an absolute prohibition of certain paints, nor an absolute governing effect towards the use of environmentally "better" paints.

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<sup>33</sup> Judgement of the Court of 2 April 1998, C-213/96 Outokumpu, para. 30.

<sup>34</sup> Judgement of the Court of 2 April 1998, C-213/96 Outokumpu, para. 31-32.

To start with, if a tax shall direct boat owner's into purchasing less toxic paints, it has to be decided what less toxic is. If a tax does not fully consider the complexity of the varying risks for different paints, it might have the effect that it could promote more toxic paints. For example, if the tax is proportional only to the copper content of paints, it could promote paints with low copper content and high zinc or other added substances. The aggregate risk of such paint might be higher than a high copper paint. If the tax instead would be proportional only to the quantity of paint, boat owners might choose to buy paints with higher toxicity and paint less or dilute the paint themselves. A crucial aspect is therefore to define criteria for tax calculation that will have the result that if boat owners avoid paints with the higher amount of tax, the total risk or total pollution caused by antifouling paints will be reduced.

There are moreover some other possible side-effects that might arise. A tax on all biocide paints would possibly promote biocide-free paints such as silicone-based paints, which might not be preferable since these paints might have another kind of negative effects on the (marine) environment. Another issue is that results from BONUS CHANGE research show that some boaters use paints that are not allowed for leisure boats. If paints are to be taxed, paints that are only allowed for ships over 12 m length should also be taxed to avoid that more boaters use such paints.

Boating is an overall relatively expensive activity. The antifouling paint only constitutes a minor part of a year's total expenses. It could therefore be questioned if and to what extent a tax would affect boat owners' choice of antifouling technique. However, even if the expenses related to antifouling is a small part of the total expenses, a tax on paints could potentially be an advantage for alternative antifouling techniques.

## Eco-labelling

Most eco-labels (such as the Nordic Swan) are voluntary labelling systems for various consumer products, intending to affect the consumer behaviour. A product (e.g. coffee) with an eco-label is seen as more desirable by consumers who want to reduce their environmental impact. An eco-label can attract customers and create a positive image among the stakeholders. In addition to voluntary ecolabels, there are also some mandatory ecolabels in certain product groups, also known as green stickers, such as EU Energy Label describing the energy consumption of household machinery.<sup>35</sup> Eco-labelling can be used for products, e.g. paints, but other types of eco-labelling in the form of certification schemes may also be used for different facilities, e.g. marinas or harbours (see further in Chapter 7).

In legal sense, whoever can establish a new voluntary ecolabel, creates its criteria (set of good practices, sustainability standards etc.) and start granting rights to use this new ecolabel. A party willing to use this voluntary label then undertakes to obey these criteria and usually reimburses some administrative and supervisory expenses through an application fee to the label organisation. A voluntary eco-label is thus based on private law contracting when mandatory ecolabels derive from law.

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<sup>35</sup> Additional to the green stickers, legislation can demand for some mandatory texts as "dangerous" in certain product groups. Although the main purpose of these is to steer the product use instead of the product choice, they verge on labels by describing the product as risky.

Even a voluntary ecolabel can still be based on public law. The Nordic Swan is based on the decisions of Nordic Council of Ministers and the EU Ecolabel has its legal ground in EU Regulation (2010/66/EC), its management is carried out by the European Commission and the national competent bodies in every Member State.

Eco-labelling as an option will be described and discussed more in detail in the next-coming chapter (Chapter 7).

## Conclusions

The regulation of antifouling paints and practices addresses many different actors and decision processes on varying regulatory levels. Nevertheless, it seems that the legal framework is not used to its full extent to prevent pollution from leisure boats' antifouling substances. This means that there still might be some options within the existing regulatory framework to address the harmful effects of toxic antifouling substances.

From an environmental quality perspective, national limit values for relevant antifouling substances both obliges the relevant authorities to act and also give them wider possibilities to do so. It seems that antifouling paints have only, to a limited extent, been addressed as an important environmental issue in the River Basin Management Plans (RBMPs) and marine strategies, at least in Denmark and Finland. Thus, there might be a potential for an increased focus on substances used in antifouling paints in the environmental quality regulation, both as regards environmental quality standards and the programmes of measures.

Regarding the availability of antifouling products on the market – and possible (geographic) restrictions on the use of certain products, the EU legislation lays down a harmonised framework for national authorisation procedures. It seems, however, that the Biocidal Products Regulation may leave some room for manoeuvre at national level, e.g. to restrict the use of harmful products in sensitive areas such as the Baltic Sea. It is, however, not yet clear how much leeway that the Member States will be granted.

Boat owners are central actors buying and using the antifouling paints. Also the marinas and boat clubs are important because this is where activities related to antifouling takes place. In general, these actors cannot be directly targeted by obligations through environmental quality legislation in the form of RBMPs and marine strategies (and their associated Programmes of Measures, PoMs). Nevertheless, the PoMs can be suitable for identifying appropriate measures to be taken by the local authorities, to address antifouling issues in marinas. Environmental protection law and waste law addresses these actors directly, but smaller leisure boat marinas and boat clubs are generally excluded from permit requirements and also to some extent from extensive waste management requirements.

Similarly, environmental protection law and waste law puts responsibility on boat owners regarding antifouling activities and waste management. Regarding the activities of boat owners and marinas, the regulatory problem rather seems to be related to supervision and enforcement than to lacking legislation. It must, however, be kept in mind that supervision of individual boat owners is resource demanding. Additional direct regulation of these actors' activities may therefore not be the only answer leading to better environmental protection.

Nevertheless, it is possible that, in particular, the use of local regulations or harbour regulations could be strengthened for example regarding maintenance activities (scraping, washing etc.) with the purpose to minimise the contamination of soil and water. Another alternative can be to encourage marinas, boat clubs and boat owner associations to develop Code of Conduct and berth rental contracts that require boat owners to reduce their use of antifouling paints, handle waste properly, consider the environment during maintenance work etc. Liability for contamination and clean-up could work as an incentive to promote such development. Improved supervision and enforcement of marinas' and boat clubs' responsibilities could also create such an incentive. This could be further strengthened through a general permit requirement for leisure boat marinas, which sets conditions on antifouling activities and waste management for a permit to be granted.

Whether economic incentives or disincentives, e.g. an environmental tax on biocidal paints, is an option depends on the EU legal framework and in particular the prohibition on discriminatory internal taxes. Furthermore, alternative governance approaches could be considered as complements to the existing regulations. Similarly, information campaigns etc. are also relevant complementary options that could be significantly developed and used for reaching the actors involved.

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## Chapter 7

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### Eco-labelling – a way forward?

*Helena Strand and Burkard Waterman*

The public concern for the environment has increased during the last decades and so has also the concern for the impact that our consumption has on the environment. The products and services that we consume result in a number of ecological footprints. The metals in our smartphone have to be extracted and transported, driving the car leads to emissions of greenhouse gases and when you have finished your milk package, you're left with a cardboard that has to be discharged somehow.

Eco-labels intend to help us as consumers to make more environmentally friendly purchase choices, being a more credible alternative than manufactures own self-claimed green advertisement. By accrediting a product (or service) to an eco-labelling scheme, the manufacturer wants to communicate something about the product's environmental attribute which may be hard to grasp just by looking at the item. The label can for example inform us about how the product has been produced, what it contains (or not contains) or that the specific content makes it possible to recycle.

This chapter explores in what way eco-labels can contribute to reduce the spread of toxic compounds from antifouling paints used on leisure boats in the Baltic Sea. First, we give a short background to eco-labels as a concept and instrument. Thereafter we discuss different eco-labelling options in the context of leisure boat antifouling, and how they can support a change towards sustainable consumption of antifouling products, techniques and practices.

### Eco-labels' history, present and future

The emergence of eco-labels can be traced back to the 1980's and 90's. By that time, there was a general increase in the public environmental awareness in many countries. In combination with a growing and widespread mistrust towards manufactures' self-claimed environmentally friendliness (Harrison, 2008), eco-labels were seen as a salvation to consumers' scepticism and a forceful response that would help and guide people in their daily purchase decisions.

Eco-label as a concept and approach has also made its way to the international policy arena of sustainable consumption and sustainable development. At the United Nation Conference on Environment and Development (UNCED) in Rio 1992 (also known as the Rio Conference or the Earth Summit), the nations of the world gathered to jointly agree upon guiding principles for sustainable development. These were formulated into an action plan called Agenda 21. At the conference, the unsustainable patterns of production and consumption were identified as severe causes of environmental degradation. Therefore, Agenda 21 encourages countries to promote more sustainable consumption patterns (Horne, 2009; UN, 2002). At the following Earth Summit meeting in Johannesburg in 2002, the world reaffirmed their commitments from Rio through the Johannesburg Plan of Implementation (JPOI). This plan required actions at all levels to:

*“Develop and adopt, where appropriate, on a voluntary basis, effective, transparent, verifiable, non-misleading and non-discriminatory consumer information tools to provide information relating to sustainable consumption and production, including human health and safety aspects [...]” (§15e UN, 2002).*

In the more recently adopted Agenda 2030 and related Sustainable Development Goals (SDG), the 12<sup>th</sup> goal states that countries should ensure sustainable consumption and production patterns (UN, 2015).

Although all of these commitments are of voluntary character, they are nevertheless influential since they set principles guiding the action of national governments as well as international organisations, business and industry and other non-state actors.

Today, there is no question that eco-labels are central for sustainable consumption which, in turn, is an important mean to achieve sustainable development as it aims to limit the negative effects consumption has on the environment.

### What is an eco-label?

As we already have mentioned, eco-labels provide information to consumers. They are consequently put on a product (or service) to communicate attributes and effects in relation to some specific environmental aspect. As a result, we are given the possibility to make more environmentally friendly consumption choices. Another positive outcome of eco-labels is also that it encourages manufactures to develop more environmentally friendly products or change their techniques and processes into production that is less harmful to the environment (Frunteş, 2014).

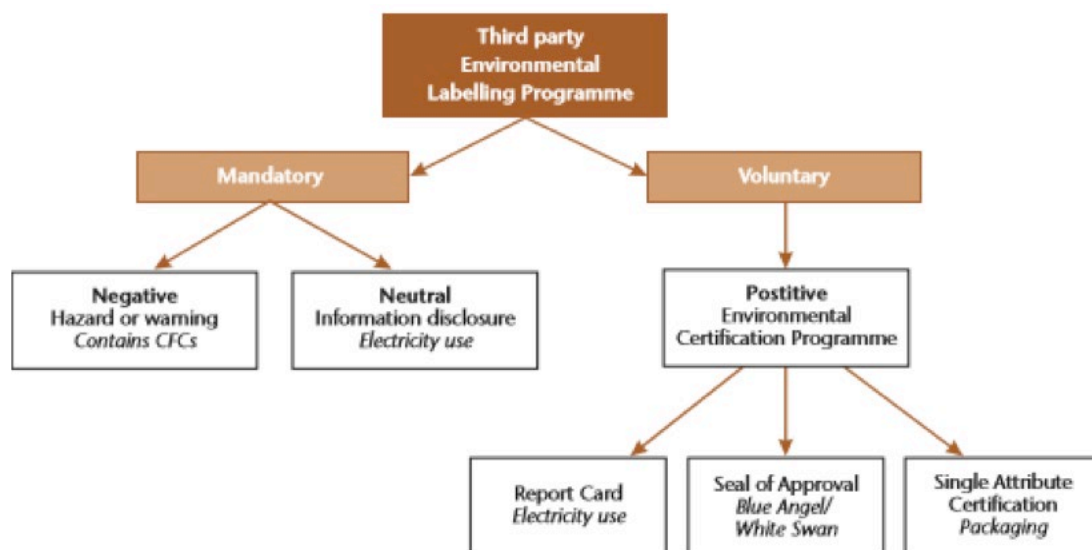
Labelling schemes can for example be designed to focus on a single sector such as forestry, fishery or the chemical industry. A label can also be designed to focus on a specific environmental issue or aspect (so called single-issue labels) or a specific phase of the product's application, such as the use of the product or its disposal/recycling. However, labels have increasingly come to apply a life-cycle approach in order to consider the environmental impacts a product contributes to, throughout the whole life cycle. The different stages range from production (raw material extraction, transportations etc.), manufacturing and distribution, and finally the use, disposal or recycling of the product (GEN, 2004). Tools such as the life-cycle assessment, LCA, make it is possible to apply a holistic approach that ensure that all relevant aspects of a product's life cycle have been considered.

In relation to the sustainability agenda, there are also labels that (either exclusively or in combination with environmental aspects) include information on social or ethical issues such as working conditions and safety (Zbicinski et al., 2007).

Labels can communicate and reveal different types of information about a product. A common distinction is made between positive, negative or neutral labels. As indicated by their names, positive labels reveal positive attributes of the product whereas neutral labels only disclose information, more in the form of a product declaration. Negative labels are mainly in the shape of warnings or to inform us about hazardous substances (Zbicinski et al., 2007). Negative information such as warnings are in most cases mandatory to reveal.

Specific for the type of eco-label that we are referring to here is that it reveal positive information and is voluntary.<sup>36</sup> In fact, obtaining a specific eco-label on a product can even be associated with certain costs e.g. as the company often has to pay an application fee when sending in the application.

We can see that there are a number of ways to design an eco-labelling scheme. This is also the case for the organizational set-up of the scheme. Labels can be initiated and owned by several actors, such as the industry, national governments or independent, non-commercial organisations. In real life, schemes often consist of a mix of these elements. For example, many programs are public in that they are initiated and funded by government departments or national agencies. However, an independent actor typically oversees and directs the activities of the program. Labels can have different geographical scope such as being national, regional or even international (Jørgensen et al., 2015). When it comes to control and verifications, this can be carried out by an independent body but there are also schemes that rely on first-party verification (Tews et al., 2002).



**Figure 7.1.** Different types of eco-labelling programmes (Zbicinski et al., 2007).

The International Organisation for Standardisation (ISO) has set up standardized principles for voluntary eco-labels and declarations. The purpose of this standardization is to provide simple guidelines and rules for how environmental aspects can be presented on a label or in a product declaration. At the same time, businesses all over the world are given international benchmarks to which they can prepare eco-labels (ISO, 2012; Frunteş, 2014).<sup>37</sup> The overall objective to standardize types of eco-labels is to:

<sup>36</sup> Vitalis (2002) distinguishes between three different types of environmental labels. The first is so-called single-issue voluntary labels, the largest grouping of labels which offers information about one aspect of the product (e.g. a product is “recyclable”). The second type is single-issue mandatory labels where information often entails negative label descriptors (e.g. warnings about toxicity or “flammable”). A third category is what to be understood to be ‘eco-labels’, namely voluntary conveying information to consumers about environmental implications associated with elements of the product’s life (Vitalis, 2002).

<sup>37</sup> ISO 14020 series ‘Environmental labels and declarations’ include: General principles; ISO 14021 – Self-declared environmental claims (Type II environmental labelling: industry and company labels); ISO

*“...through the communication of verifiable, accurate information that is not misleading, to encourage the demand for, and supply of, products which cause less stress on the environment, thereby stimulating the potential for market-driven continual environmental improvement”(ISO, 2012:10)*

The standards established by ISO have the following definitions (ISO, 2012; GEN, 2004; Frunteș, 2014):

- Type 1 Environmental labelling; a voluntary, multiple-criteria based, third party program that awards a license that authorizes the use of environmental labels on products indicating overall environmental preferability of a product within a particular product category based on life cycle considerations.
- Type 2 Self-declaration claims; informative environmental self-declaration claims.
- Type 3 Environmental declaration; voluntary programs that provide quantified environmental data of a product, under pre-set categories of parameters set by a qualified third party and based on life cycle assessment, and verified by that or another qualified third party.

Comparing the three standardization-types, a labelling scheme following Type 1 is the most comprehensive as it e.g. includes multiple criteria and authorization from an external, third-party actor. Type 2 is for example not independently verified and type 3 labelling is simply providing a wide range of environmental information and data. This type of label is however not guiding the consumer further, it is up to the individual to evaluate and judge the information that is presented.

## Development process and evaluation

Developing a labelling scheme entails a number of general steps. First of all, one has to decide and select which types of product(s) or service(s) that the label should target. Second, there is a process of developing and adopting appropriate criteria, standards or guidelines for the selected category of products. The final step is certification and licensing. This include verifying that products and services follow and comply with the criteria of the program, but also how and what type of information that should be submitted from the applicant in order to evaluate this (GEN, 2004).

The success or effectiveness of any eco-label is highly interlinked to how consumers perceive and assess its credibility since this, in the long run, implies that they are more inclined to buy the product. A number of aspects have consequently been emphasized as important to take into account because they can influence how consumers evaluate a label. These are for example: voluntary participation, compliance to environmental and other relevant legislation, consideration of “fitness for purpose” and level of overall performance of the product or service (i.e. consumers are also considering the comparable quality and performance of the product). Moreover, basing criteria on sound scientific and engineering principles is essential but also that criteria are credible, relevant, attainable and measureable. They should be verifiable in an independent, transparent and accountable way. Consistency with relevant ISO principles (such as ISO 14020, 14024) can moreover send out credible signals to consumers (SBA, 2006; GEN,

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14024 – Type I environmental labelling, principles and procedures; ISO 14025 – Type III Environmental declaration, principles and procedures (ISO, 2012).



2004). Last but not least, the issue of demand should not be underestimated; producers must be willing to certify their products and consumers must be willing to buy these products (Jørgensen et al., 2015). Consumer demand is important for the success of any label program. This is also necessary for keeping the industry interested and willing to have their products included in the labelling program (GEN, 2004).

## Why eco-labels?

Eco-labels are distinguishing more environmentally friendly products or services compared to others. Through this, they promote sustainable consumption by providing consumers the possibility to make more environmentally friendly consumption choices.

For the business and industry, it is crucial to be aware of the increased environmental awareness among consumers and respond to their demand and deal with negative environmental effects of a product's life-cycle. Eco-labels are one mean to market their products. In fact, they can be a competitive tool to highlighting the benefits of a specific product compared to others. Taking environmental considerations can thereby be an important market advantage for companies. Based on this, eco-labelling schemes function as so called market-based instrument or new environmental policy instruments (NEPIs). It is a different approach to bring about changes in e.g. consumption behaviour compared to more traditional forms of command-and-control measures where national governments steer behaviour by implementing and enforcing laws or regulations (Tews et al., 2002). Instead, environmentally friendly consumption is driven by market interest, consumer demand and self-regulation (Horne, 2009; GEN, 2004).

How consumption behaviour can be changed to become more environmentally friendly and sustainable is something that has concerned researchers from various disciplines (e.g. sociology, economics, and psychology). The rationale for eco-labels is that individuals, motivated by environmental values and beliefs, want to reduce their environmental consumption impact and they can do this by choosing environmentally friendly products. It is therefore essential to provide consumers with accurate and comparable information about environmental aspects, otherwise they will not be able to express their environmental preferences.

*“...if consumers are confused to the point where they cannot distinguish between competing products in terms of environmental performance, they are unable to express preferences through their purchases” (ISO, 2012:8).*

Eco-labels are filling this gap. The information communicated by the label is something that the consumer considers and weighs (e.g. against price, quality etc.) before making the decision whether to buy the product (Schaefer & Crane, 2005).

This understanding for how we can promote sustainable consumption implies that consumers are rational and self-interested decision-makers. It is however an assumption that has been questioned (Moisander et al., 2010). The critique argues for example that consumption is more multidimensional. Instead of overemphasizing the role of individuals and their personal values and attitudes, we are also influenced by the world we live in and the social and cultural norms that exist around us when we consume (Schaefer & Crane, 2005; Peattie, 2010). Other factors can be of structural type such as nudges, what products that are available and how incentives are structured (Sachdeva et al., 2015). Research has also illustrated how material elements and physical objects can influence consumption practices. This is something that is lacking in the line of research of more individualistic or cultural approaches (Shove et al., 2012).

Moreover, we are now facing a situation where we find many different and separate labels, and new ones are constantly introduced. This leads to a situation where labels, instead of guiding and helping rather become a confusing element. It has been described as “... too many products, too much information, too little time, and a paucity of independent, accessible, readily accessible and understandable information about environmental performance” (Horne, 2009:180).

It becomes clear that sustainable consumption is a complex issue. Product information communicated on labels is important, but may not be the only factor influencing consumption choices and might therefore not be the single salvation to overcome unsustainable consumption.

## **How can eco-labels contribute to more sustainable antifouling practices and consumption?**

When it comes to antifouling of leisure boats, a few critical consumption choices can be identified that directly or indirectly contribute to the spread of toxic compounds from biocidal antifouling paints. These are: i) choice of antifouling method and ii) how maintenance practices are performed.

- i) To paint the hull with biocide containing antifouling paints is the most widely used method keeping the hull free from fouling. Biocides and other chemicals erode from the paint and are released into the water where they accumulate in the sediment on the seabed. This has severe effects for the marine environment and the organisms living there (see Chapter 3).
- ii) Biocides from toxic antifouling paints can also spread when the boat is maintained, for example when the painted hull surface is scraped or sanded, by washing or high-pressure hosing the boat hull but also when the boat owner paints on new layers of antifouling paint. If not properly collected, paint flakes (or drops) can fall on the ground and diffuse to the surrounding environment, leading to contamination of soil in boatyards (see Chapter 3).

At the same time, there are sustainable consumption options. A number of environmentally friendly antifouling methods and techniques have been developed finding their way to the market. BONUS CHANGE research has also found that many of these alternatives works very well in the Baltic Sea (see Chapter 4). Since these options are biocide-free, consumption of these alternatives would eliminate or reduce the spread of these toxic biocides from antifouling paints. Moreover, with appropriate protective measures and caution (e.g. protecting the soil), maintenance of boat hulls can be performed with limited environmental effect as spread of biocidal paint flakes is minimized.

We can conclude that there are possibilities for boat owners to make sustainable consumption choices when it comes to choosing antifouling methods and how to maintain the boat. So in what way can eco-labels support this change? This is discussed in the remaining parts of this chapter. By providing an overview of different labelling options, namely labelling of i) antifouling products and methods, ii) boats and iii) antifouling (maintenance) service, we will show how the different approaches could help to achieve the objectives of the BONUS CHANGE project.

## Eco-labelling of products and other antifouling methods

When discussing labelling of antifouling products and methods, it is important to be aware of the many different methods, paints and techniques that exist. These are also functioning in slightly different ways (based on Watermann et al., 2004; Lüsckow, 2011).

- *Eroding biocide containing antifouling paints.* This category can be further divided into two sub-groups of ‘conventional’ or *free associations paints and the self-polishing coating (SPCs)*.<sup>38</sup>
- *Non-eroding biocide antifouling paints.*<sup>39</sup>

Biocide-free methods include:

- *Biocide-free antifouling paints.*<sup>40</sup>
- *Mechanical techniques.*<sup>41</sup>

## Labelling requirements and existing schemes

In Member States of the European Union, antifouling paints that contain biocides such as copper are regulated on the EU-level through the Biocidal Product Regulation (BPR). According to this regulation, biocidal antifouling paints are considered as biocidal products since they have a primarily biocidal function (Product type 21, regulated in Regulation (EU) No 528/2012). Because of this, there are specific requirements for biocidal antifouling paints when it comes to authorisation, registration but also some labelling requirements. The BPR lists a number of points that has to be included on the label of the biocidal antifouling product, for example related to antifouling characteristics and ingredients (Article 69, Regulation (EU) No 528/2012). Since the listed requirements to a large extent concern disclosure of neutral information, it can be difficult for the consumer to evaluate and assess the information, especially for non-trained users. Moreover, the BPR also states that:

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<sup>38</sup> The conventional type of paint lacks chemical binding between the paint matrix and the biocide(s). The active substance (biocide) is released and physically dispersed from the paint matrix in contact with seawater. SPCs implies that at least part of the main biocide is chemically bound to the paint matrix. For long time TBT was the most used biocide which now, to a large extent, has been replaced with copper.

<sup>39</sup> This type of paint implies that only the biocide diffuses from the paint matrix. The paint film is left leading to reduced rate of biocide-release and eventually no more biocides can be released and the antifouling performance drops dramatically (Watermann et al., 2004; Lüsckow, 2011). Because of this, these paints have a steadily decreasing share of the market (Watermann et al., 2004).

<sup>40</sup> The paint has an adhesive film that hinders attachment of organisms through special design of the surface. The non-eroding coatings include non-stick coatings such as silicone or Teflon-based paints that create low surface energy which means that limited fouling takes place. Some biofouling can occur but the attachment of the fouling organism is weak and can thereby easily be removed. Fiber coatings is another type that deters settlement of fouling (Watermann et al., 2004).

<sup>41</sup> Based on basic principles such as physical protection, scraping or cleaning, boat owners can keep the boat hull free and from attachment and growth of marine biofouling (see also in Chapter 4).

*“Authorisation holders shall ensure that labels are not misleading in respect of the risks from the product to human health, animal health or the environment or its efficacy and, in any case, do not mention the indications ‘low-risk biocidal product’, ‘non-toxic’, ‘harmless’, ‘natural’, ‘environmentally friendly’, ‘animal friendly’ or similar indications.”  
(Regulation (EU) No 528/2012, Article 69).*

This means that it is not possible to label a biocidal antifouling paint with claims that can be misleading for the consumer in respect of the risks of the products to humans, or the environment as well as the efficiency. Manufacturers must comply with the provisions of the BPR meaning that these label requirements not are equivalent to the voluntary character of an eco-label.

According to the BPR, biocide containing paints are also required to undertake risk assessment tests showing the products’ effects on humans and the environment. Moreover, the applicant has to prove and verify the product’s efficiency against the fouling organism it is supposed to target.<sup>42</sup> For biocide-free paints, the situation looks quite different. Since they do not contain any active ingredient (biocide), they are not subject to any registration or approval procedure similar to their biocidal counterparts. Nevertheless, paint products have to fulfil REACH requirements<sup>43</sup>, regulations on Volatile Organic Compounds, VOCs (2004/42/CE), as well as regulations of the labelling directive and classicisation (EC No. 1272/2008), packaging and labelling of dangerous substances i.e. negative information labelling requirements in the form of warnings (Watermann et al., 2004; Ytreberg et al., 2010). The mechanical antifouling methods are not subject to any approval process nor comprehensive labelling requirements. The biocide-free antifouling paints and mechanical methods are not required to carry out efficacy tests and there has been no neutral or standardized testing of biocide-free products (Watermann et al., 2004).

The Nordic Swan and the EU eco-label (EU flower) are examples of eco-labelling schemes, established in the Baltic Sea region. Both schemes have certificates related to paints. However, they only apply to indoor and outdoor paints, varnishes and wood stains (and related products covered in the scope of Directive 2004/42/CE). It is clearly stated that the label-schemes do not include antifouling coatings (EU Commission Decision 2014/312/EU; Nordisk Miljömärkning Svanen, 2017).

## How can eco-labelling of products and other antifouling methods be used?

The advantage of using eco-labelling for antifouling products is that it would be possible to distinguish more environmentally friendly options, which can support and promote sustainable consumption of biocide-free alternatives. Existing labelling requirements or voluntary eco-labelling schemes are so far specific to the separate product categories. However, bearing in mind that marine biofouling can be combated through a number of

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<sup>42</sup> Efficiency defined as the “ability of a product to fulfill the claims made for it when used according to the directions for use on the proposed product label” and can be carried out in accordance with a number of standard protocols (ECHA, 2017).

<sup>43</sup> REACH is an EU regulation aiming to improve the protection of human health and the environment from risks that can be posed by chemicals. In principle, it applies to all chemical substances also those used in our everyday-lives e.g. cleaning products and paints (ECHA, REACH, 2017).

different means other than just biocide paints, it might be more helpful for consumers to have a comprehensive scheme for the broader category of antifouling methods. It would make it possible to differentiate the sustainable options by comparing the many different antifouling options that exist, products and methods. Today there is no such eco-labelling scheme. However, since the biocidal paints are regulated differently compared to biocide-free products and methods, this may not be possible. According to the provisions of the BPR stating that biocidal paints should not have labels with misleading information such as claims of being “environmentally friendly”, including biocidal antifouling paints in a comprehensive eco-labelling scheme could therefore be restricted.

Instead, an eco-label could be designed for the biocide-free antifouling techniques and paints. Moreover, such scheme may also include information about the technique or product’s performance, both in relation to environmental aspects but also assurance on its antifouling efficiency. This is to promote biocide-free options and provide an alternative because today, marketing of antifouling paints is made with strong linkages between the content of copper and the product’s efficiency (see Chapter 5).

Labelling of antifouling products and methods is highly important for restricting new input of biocides from antifouling paints into the Baltic Sea. However, this approach does not target how antifouling maintenance practices are performed, identified as a second important source through which biocides from antifouling paints are spread. Although direction of use for example should be included in product information of biocidal products (according to the labelling requirements of the BPR), these specifics can only be seen as directional since compliance is not controlled.

## Eco-labelling of boats

Another eco-labelling approach is schemes aimed for boats. It becomes relevant to our case of antifouling since it would be possible to include labelling-criteria both in regard to the choice of antifouling methods and how the boat is maintained. The approach of targeting the boat and boat owner directly is moreover important since most boat owners e.g. in the Nordics do the boat maintenance work themselves.

## Existing labelling schemes

Over the years, a number of sustainable shipping initiatives have been established generally intended to improve the environmental performance of shipping (a comprehensive overview of existing programs is provided by Pike et al., 2011). One concrete example is the Blue Angel<sup>44</sup> Eco label for environmentally friendly ship operations aiming to reduce emissions and release of harmful substances. It includes one optional criteria related to antifouling, “Use of biocide-free antifouling paints and systems or biocide-free coatings, respectively” (Blue Angel, 2015). On the other hand, these shipping eco-labels are not targeting leisure boats specifically. The Blue Angel-label is for example only applicable to larger vessels and passenger ships.

There are however exceptions. The Blue Flag, an international voluntary eco-certification program, has a label for leisure boats. The program is in the form of an Environmental

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<sup>44</sup> The Blue Angel, a forerunner of national eco-labelling programs, established already in 1977 in Germany.



Code of Conduct for private boat owners. Boat owners that want to certify their boats are consequently required to comply with the code. Antifouling is not an issue that is specifically mentioned but could only be interpreted to be included in the quite broad and vaguely formulated requirement which states that “I will use the most environmentally friendly products that are available and work efficiently” (Blue Flag, 2017).

## What are the potentials for eco-labelling of boats?

In spite of promising potential of this labelling approach (i.e. a labelling scheme that could include criteria targeting both choice of antifouling methods but also how maintenance practices are performed), these potentials are poorly utilized in the labelling schemes that exist today. This is because they, to a limited extent, have been designed to target leisure boats in combination with criteria for antifouling methods and practices.

However, even if an eco-labelling scheme for leisure boats would include criteria targeting antifouling, there are other structural conditions which can constitute barriers to what extent boat owners are able to comply with such criteria. For example, much sustainable antifouling methods and maintenances are dependent on specific marina infrastructure (e.g. whether there is a wash-down pad with water treatment in the marina). If the infrastructural solutions are not present in marinas, boat owners have limited possibility to change into sustainable antifouling practices.

Another problematic issue for a labelling scheme targeting individual boats and boat owners, is that supervision becomes difficult and resource demanding when it comes to ensure compliance with the self-committed measures. Moreover, there may be little incentives for a single boat owner to apply to this type of voluntary program, other than those that are already convinced and environmentally conscious. The risk is therefore that a label also will have limited effect.

## Labelling of antifouling services: infrastructure and maintenance practices in marinas

Marinas are highly important sites because this is where boat owners keep their boats and perform much of the antifouling related activities. The way that marinas are designed can have profound effects for antifouling practices.

Infrastructure and services in marinas supporting sustainable practices can for example include designated sites where the boat should be washed and cleaned, litter and recycling bins where paint cans and other hazardous waste can be disposed properly, or provision of protective sheets or vacuum cleaners to collect paint flakes that are removed when the boat is sanded or scraped. Moreover, mechanical and technical antifouling methods are in some instances in the form of infrastructure (e.g. boat washer) whilst other require some infrastructure to work (e.g. poles by the boat mooring needed for hull covers). Whether boat owners realistically can choose sustainable antifouling methods or maintenance practices, depend on the marina's provision of services and infrastructure.

The importance of infrastructural conditions in marinas is illustrated by research in the BONUS CHANGE project (see Chapter 4 and Chapter 5). The research also demonstrates that equally important to the physical infrastructure, is the set-up of rules, regulations or codes in the marina (so called institutional infrastructure). These rules can be formulated to support the use of sustainable antifouling infrastructure and penalize

unsustainable practices. Private law arrangements, such as “Code of Conduct” in a specific marina, can be seen as a contract between the boat owner and the marina where it is possible to include provisions on e.g. how antifouling maintenance should be practiced. There are examples where marinas have included behavioural standards and target the choice of antifouling method, e.g. by stating that it is not allowed to paint the hull with biocide containing paints in the marina (e.g. as in Bosö Båtklubb, 2017).

To conclude, marinas can promote both biocide-free antifouling methods and at the same time improve the maintenance practices. To what extent a marina eco-labelling scheme include these aspects (specifics in relation to services and infrastructure<sup>45</sup>) is highly decisive for limiting the use and spread of toxic compounds from biocide containing antifouling paints.

## Existing labelling schemes

There are a number of international eco-labelling schemes for larger industry ports, but also examples of national programs targeting leisure boat marinas. For example, in Finland, the association “Keep the Archipelago Tidy” has introduced a voluntary eco-program which includes measures to ensure appropriate waste and wastewater management for marinas (Håll Skärgården Rent, 2017). On the local level, there are several examples around the Baltic Sea where individual marinas have adopted ambitious environmental programmes or Code of Conduct in order to target unsustainable antifouling practices (e.g. Bosö Yacht club’s port and shipyard regulations, Bosö Båtklubb, 2017). Marinas can also establish environment and quality systems, implemented and certified by ISO norms (ISO, 2012; ISO, 2015). This means that the marina applies practices in order to monitor its activities in a rigorous way. What concerns the regional eco-labelling schemes of the Baltic Sea area (e.g. the Nordic Swan and the EU eco-label), no program for marinas have been developed. However, they have established labels for service-related issues such as cleaning, data centres, food and catering services meaning that they potentially also could develop schemes for marinas, although they are currently not doing so.

There are a few examples of eco-labelling schemes with cross-country scope which target marinas for leisure boats specifically. The table below (Table 7.2) presents an overview and comparison of two of these programmes, namely the Blue Flag Marina programme and the International Clean Marina Programme (ICMP).<sup>46</sup> While these programmes have quite different geographical scope (the Blue Flag is an international programme while the latter mainly covers Australia and Asia Pacific), a comparison provides interesting insights in the set-up of larger labelling schemes and to what extent antifouling practices and infrastructure are issues included.

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<sup>45</sup> Infrastructure may also include communication channels or information-related infrastructure such as SMS-alarms for barnacles applied on the Swedish east coast, warning the boat owners when barnacle larvae are present in the water and may attach the boat hull. This indicates the optimal time to wash the boat (Skärgårdsstiftelsen, 2017).

<sup>46</sup> Comparison of characteristics considering a label’s quality assurance. Based on Nilsson et al. (2004), slightly modified.

**Table 7.2.** Comparison of the Blue Flag Marina programme and the International Clean Marina Programme.

|   | Blue Flag for marinas<br>(Blue Flag 2015)  | International Clean Marina Program<br>(Marina Industries Association 2017;<br>ICMP 2007)  |
|---|--|---|
| <b>Objective</b>                                    | Overall encompassing sustainability scheme; sustainable development in freshwater and marine areas. It encourages the public to learn more about their environment by promoting environmental education activities and display of information, permanent and relevant to the site in terms of biodiversity, ecosystems and environmental phenomena.  | To reduce “non-point source pollution” <sup>47</sup> associated with marinas/boating facilities and to promote clean water and air for a thriving marina industry business. Incentive-based education and outreach program encouraging environmental compliance and use of best management and practice.  |
| <b>Ownership</b>                                    | Owned by the non-governmental and non-profit organization FEE (Foundation for Environmental Education) in partnership with a number of international organizations, associations and research institutes. Specific structure with international unit (jury and audit) and the equivalent on country levels.  | Program of the Marina Industries Association (MIA) which represents the marina industry in Australia and the Asia Pacific. The program is furthermore supported by a number of institutional actors and non-governmental organizations.   |
| <b>Eligibility</b>                                  | A global-wide certification scheme established in 1985 in France. Applicants can be a local municipality, private hotel, national park or private marina operator. The marina must have pontoons or piers for pleasure boats wither located in inland waters or at the coast. It can be a part of a larger harbour but with a clearly designated area i.e. separated from other harbour activities. A number of marinas around the Baltic Sea are accredited to the program (information about accredited sites can be found on <a href="http://www.blueflag.global/">www.blueflag.global/</a> ). Costs are associated with accreditation. | Applicable for clubs, boat clubs, slipways, bot yards and associated industry operators mainly from Australia, New Zealand, the Asia Pacific and the Middle East. The related costs depend on the level of accreditation.   |
| <b>Quality assurance scheme and criteria set up</b> | For marinas, a Blue Flag scheme is constituted by a set of criteria, both imperatives and guidelines. The imperatives must be complied with in order to be awarded the Blue Flag. The criteria are minimum requirements and national programs can choose to have stricter criteria. The Blue flag is awarded every year/season and is only awarded as long as the criteria are fulfilled.<br><br>External assessment by the national audit team each year.   | Level 1-4 of accreditation. For level 3; the program provides a long set of criteria and to gain accreditation, at least 85% of the criteria has to be fulfilled but there is no specification in terms of imperatives or guideline criteria. Each criteria is accompanied by a description specifying the potential environmental impact and effects of the activity i.e. justifying the relevance of the criteria. Thereafter, a number of requested management practices are described for how this activity can be changed/improved, followed by a “check-list – question.<br><br>External assessment is part of Level 3 accreditation, undertaken every three years. |

<sup>47</sup> Non-point sources of pollution occur when water runs over land, picks up pollutants and then deposits them in surface waters. Mismanaged pollutants from everyday marina activities can enter a marina basin as non-point source pollution.

|  | Blue Flag for marinas<br>(Blue Flag 2015)   | International Clean Marina Program<br>(Marina Industries Association 2017;<br>ICMP 2007)  |
|--|---|---|
| Examples of infrastructure and maintenance related criteria with relevance for antifouling | <p>– <b>Waste:</b> imperative to have segregated facilities for at least three different types of hazardous waste such as paints, boat scrapping, antifouling agents, the provision of other litterbins and facilities for receiving recyclable waste materials</p> <p>– <b>Water:</b> imperative to have toilet tank waste reception, sanitary facilities. Moreover, If the marina has a boat repairing and washing area, no pollution must enter the sewage system, land or water<sup>48</sup></p> <p>– <b>Maintenance of infrastructure:</b> buildings and equipment properly maintained in compliance with national legislation</p> | <p>– <b>Painting and fiberglass repair:</b> criteria for abrasive blasting, hull and topside painting, including description of best management practice of “do not allow in-water hull scraping or any process that occurs underwater to remove paint or biofouling from the boat hull” (checklist question “do you conduct boat scraping, sanding and other debris-producing maintenance in a designated hardstand maintenance area, where feasible?”).</p> <p>– <b>Preparation and painting boat hulls:</b> criteria such as ‘use of antifouling paints and coatings’ (checklist questions are “do you recommend less environmentally damaging hull coatings?”, “do you disallow in-water hull scraping or any process that occurs in-water/underwater to remove painting from the hull”, “do you contain the dust from boat hull preparation work and sanding?”), scraping and sanding, varnishing and teak refinishing.</p> <p>– <b>Slipping/lifting/recovery and storage of boats:</b> criteria for bilge cleaning, pressure washing (treat wash water before discharged), pump-outs, fuelling.</p> <p>– <b>Facility management:</b> including litter and recycling, facility cleaning.</p> |

As seen, both programs are broad in their sustainability approach and not solely targeting antifouling in specific. Criteria for infrastructure and practices related to antifouling are more emphasized in the ICMP. However, to gain accreditation to the ICMP, 85% of the measures have to be met meaning that the program itself does not weigh what issues that are most important to comply with. This is up to the marina to decide and could imply that the antifouling-related criteria are disregarded.

Both the Blue Flag and ICMP include criteria for establishing a Code of Conduct. This is an imperative criteria in the Blue Flag (Blue Flag, 2015:3) whereas ICMP encourages marinas to include good environmental boating practices in customer contracts or to set up a list of “rules” for the boat owners who do maintenance work themselves (ICMP, 2007).

## How can eco-labelling of antifouling services (infrastructure and maintenance practices) in marinas be used?

Eco-labelling of a marina can contribute to both reduced input of biocides as well as restricting the spread of already existing antifouling paints. As a result, there are large potentials to minimize spread of toxic compounds. In spite of this promise,

<sup>48</sup> A marina with boat repairing and washing area needs to comply with national and international legislations: the boat repairing and washing must take place in a specifically designated area in the marina, the collected waste must be handled as hazardous waste (Blue Flag, 2015).

there is currently no regional eco-labelling scheme in the Baltic Sea area that include infrastructure and service-related specifics for antifouling, nor antifouling practices (i.e. choice of antifouling methods or how maintenance should be practiced).

A marina labelling program that include behavioural criteria (e.g. in form of Environmental Code of Conduct) accompanied with adequate sanctions implies that supervision can take place on a smaller scale (e.g. by board members or marina employees). It can thereby be more resource efficient compared to supervision and enforcement of public law which often are responsibilities vested by national or local authorities. They could thus work as a complement (see Nilsson et al., 2015; Kymenvaara et al., 2015; Baaner et al., 2015).

Infrastructure aimed to limit the spread of dust and paint flakes from maintenance work is foremost relevant if the boat hull has been painted with biocide containing antifouling paint. As this is the most commonly used antifouling method applied by leisure boat owners today, and results from BONUS CHANGE research indicates that only a small percentage of the boat owners seems to be willing to scrape off old paint layers before using environmental friendly alternatives, targeting maintenance practices will be important even in a foreseeable future. Nevertheless, to remove all old antifouling paints should be required before applying any non-biocidal coatings or mechanical methods. This kind of specifics could e.g. be included in a marina's Code of Conduct.

Labelling a marina as eco-friendly can be an important trademark for the individual marina and also a way to attract boat owners, especially those who are environmentally conscious. However, if an eco-labelling scheme requires services and infrastructure to be set up, this also means costs and efforts for the marina in order to implement the measures and ensure compliance to criteria. Yet, in a longer perspective, these investments can be economical since it, for example, minimizes the risk of contaminating the land in boatyards. It would mean less costs if the marina is required to handle and clean-up contaminated soil and sediments (Kymenvaara et al., 2017). There are also cases where funding and economic support programs have been introduced, working as incentives for marinas to make these investments. In Sweden, it is for example possible to apply for funding to partly finance installations of e.g. boat washers or wash pads (Locally water management projects, Lokala vattenvårdsprojekt LOVA, Regeringskansliet, 2011). Such funding is important to support the expansion of sustainable infrastructures in marinas.

## Final remarks

Leisure boat antifouling is interlinked to a number of consumption choices which directly or indirectly contribute to the spread of toxic compounds from biocidal antifouling paints, namely the choice of antifouling method and how maintenance practices are performed. This chapter has explored how eco-labelling schemes can support a change of current antifouling practices to become more sustainable and contribute to reduced supply of toxic compounds from antifouling paints. Based on our mapping and discussion of different labelling approaches, we can conclude a number of things:

First, antifouling products and methods are regulated differently. It can therefore be difficult to establish a comprehensive eco-label that includes all different antifouling methods. Nevertheless, introducing an eco-label for biocide-free methods can guide



consumers and support consumption of environmentally friendly antifouling methods. This labelling option primarily contributes to reduce the input of new biocides to the Baltic Sea. However, it does not restrict the spread of compounds from hulls that already have been painted with biocidal paint.

Secondly, eco-labelling of boats could promote biocide-free antifouling methods and also sustainable maintenance practices. This approach is motivated by the fact that most boat owners do antifouling and maintenance work themselves. However, the success of an eco-label for individual boats and boat owners can be restricted by structural conditions such as lack of marina infrastructure that supports sustainable antifouling methods and maintenance practices. These issues are important barriers but are outside the control of the individual boater. The risk is consequently that this eco-label option has limited effect.

Finally, an eco-labelling scheme for marina services seems to be the most promising labelling approach to support BONUS CHANGE objectives. This is because an eco-label for marinas can include requirements of services and infrastructure. Through this, biocide-free antifouling methods and techniques as well as sustainable maintenance practices can be promoted which could reduce the input of new toxic compounds meanwhile limiting the spread of compounds from paint that already exist on boat hulls. As a result, antifouling can be approached more comprehensively as it is possible to address structural conditions, material objects and behaviour (e.g. through Code of Conduct), aspects that also have been highlighted in sustainable consumption literature and research.

The already existing eco-labelling schemes for marinas differ in terms of their geographical scope, their objectives and what type of marinas they are targeting. However, they are not addressing antifouling services to the desired extent. Moreover, to promote coherency throughout the Baltic Sea region, a labelling scheme covering all countries would be preferable. This means however that existing regional programs such as the Nordic Swan or the EU eco-label, have insufficient geographical scope since they do not include Russia, which rather justifies an international program or adaption of existing international schemes.

Our mapping of different existing schemes and approaches shows that antifouling, in general, is a blind spot in many eco-labels today, leaving much room for improvements.

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## Chapter 8

### Towards sustainable consumption and the way forward – the case of antifouling

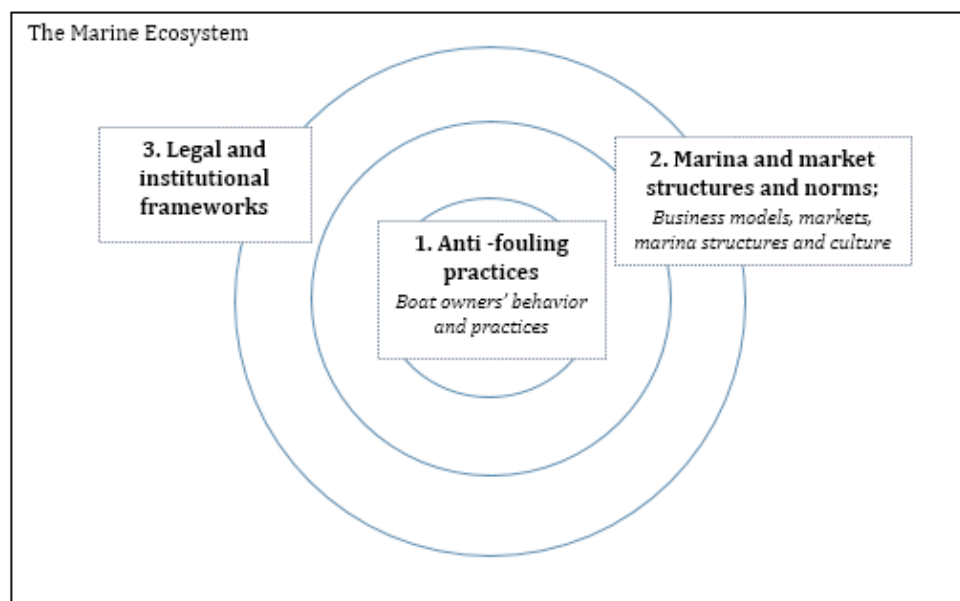
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The Baltic Sea is a unique marine ecosystem. At the same time, it is a vulnerable and stressed environment. A great majority of the approximately 3 million leisure boats active in the Baltic Sea's countries continuously use antifouling paints that contain and leaches toxic compounds, such as copper, to prevent fouling. Evidently, this contributes to the spread of harmful substances to sensitive coastal areas of the Baltic Sea, causing high toxicity and risk to the marine ecosystem.

The purpose of the BONUS CHANGE project has been to deliver scientific results that can help to reduce the spread of hazardous (toxic) biocides from antifouling paints used on leisure boats in the Baltic Sea, by changing antifouling practices. During the last four years, the BONUS CHANGE consortium has been dedicated to produce and gather solid and integrated research that can be used to support a change of dominant antifouling consumption and practices.

#### Antifouling consumption from a system perspective: How different levels interact in forming and influencing antifouling practices

The system model presented in Chapter 1 informs us that consumption is formed by a complex, multi-layered system. Based on this understanding, we argue that consumption in general as well as in our specific case of antifouling, is influenced by norms and cultures (the traditional way of doing antifouling and maintaining the boat or how we see 'the good sailor'), structural conditions (infrastructure in marinas, advertisements and supply of products in the marketplace) as well as laws, regulatory practices and legal sanctions.



**Figure 8.1.** Sustainable consumption from a system perspective – the case of leisure boat antifouling in the Baltic Sea.



For this reason, BONUS CHANGE research has aimed to gain deeper knowledge and understanding of the linkages between consumers' behaviour, market actors and the legal framework which affect the Baltic Sea - that all influence how we can change antifouling to become more sustainable.

In this publication, we have reported on research that has examined contamination and environmental effects in the Baltic Sea, caused by past and current antifouling practices (Chapter 2-3). We have explored how products and infrastructure can change in order to minimize the spread of toxic compounds from antifouling paints but also how today's consumption and related practices are heavily influenced by cultures, infrastructure and markets for antifouling (Chapter 4-5). Regulatory or eco-labelling options with the aim to minimise the use of toxic paints have also been analysed and discussed (Chapter 6-7).

Taken together, the research addresses the challenges of how and why unsustainable consumption patterns prevail but also providing insights to how they can be changed. The different chapters have also demonstrated how interconnected the different levels are in shaping current consumption and practices of antifouling.

An example concerns the traditional antifouling method practiced by boat owners; painting the boat hull with copper-based antifouling paint (Figure 8.1; Level 1). This unsustainable practice can be sustained because antifouling paint is the main antifouling product that boat owners find in the marketplace. Most retailers provide these products in the store and in the marketing of the paints, efficiency is linked to the copper content. In addition, the marina may not provide the infrastructure that boat owners need to change into a biocide-free antifouling technique (e.g. no available brush washer within reasonable distance or possibilities to attach a hull cover by the mooring place). There may also be a lack of infrastructure related to maintenance work (e.g. no designated area with wastewater treatment where the boat can be cleaned) (Figure 8.1; Level 2). By extension, this is governed by the legislation. The legislation allows for boat owners to use toxic antifouling paint and it has become the normalized way of doing antifouling. Moreover, in Sweden, high content copper paints are sold in areas where they not are needed or even allowed to be used and it is yet not clear if it will be possible restrict where antifouling products are sold according to the new regulations in Biocidal Product Regulation (BPR). The boat maintenance practices are regulated differently in the countries around the Baltic Sea, either targeting the environmental consequences of the practices (i.e. prohibition to cause pollution) or the practice itself (i.e. explicit prohibition of a certain antifouling practice such as high-pressure hosing, sanding or scraping over unprotected soil). However, since the regulations target different actors (marinas, boat clubs or even individual boat owners) it is resource demanding and complicated for authorities to control that they are complied with. This means that the traditional and taken for granted, yet unsustainable, ways of doing antifouling maintenance prevail (Figure 8.1; Level 3).

Another example of how boat owner behaviour, marinas and legal frameworks are connected concerns when a municipality or boat club support biocide-free antifouling techniques by installing a boat washer. A marina or boat club could also support sustainable maintenance practices by requiring that painting, sanding and scraping of the boat hull only is allowed over a protective tarp. If boat owners fail to comply with the requirements, some type of fine or other sanction is imposed (Figure 8.1; Level 2). Such arrangement will support the use of sustainable antifouling practices among boat owners (Figure 8.1; Level 1), as well as influencing norms and boating cultures of what

antifouling practices that are seen as acceptable. The antifouling practices are, to a large extent, dependent on structural conditions such as marina infrastructure. The legal and institutional framework could support sustainable antifouling by e.g. introducing funding and economic support programs partly financing installations of e.g. boat washer or proper wash pads with water treatment. This is for example possible today in Sweden. The support could consequently make marinas, boat clubs or municipalities willing to make the investments and contribute to the expansion of sustainable infrastructures (Figure 8.1; Level 3).

These illustrations are just two of many examples that could be extracted from the chapters.

The BONUS CHANGE research clearly identifies that different norms and “taken for granted” ways of doing antifouling determine how boat owners choose to avoid fouling. At the same time, it shows that sustainable consumption in the area of leisure boat antifouling is not about stimulating individual demand for sustainable products and services since consumption choices do not solely rely on the individual boat owner. It also means that we need structural changes at all levels in order create demand for sustainable antifouling products and techniques.

### The way forward – how can we CHANGE antifouling consumption?

This publication demonstrates that sustainable antifouling is a highly complex problem that requires more than one single solution in order to change. As painting with biocide-based paints remain the most popular option for boat owners, we need a transition from the traditional way of doing antifouling into new sustainable ways, including new ways for how to maintain leisure boats. The changes need to take place within all three levels that shape consumption; antifouling practices, marina market structures and norms as well as legal frameworks (Figure 8.1) meaning that various actions and efforts are needed from various actors.

Based on the gathered knowledge from the BONUS CHANGE research and findings, we propose a number of recommendations aimed to support decision-makers, competent authorities, municipalities and marinas to achieve a change to sustainable antifouling consumption, which would considerably limit the excessive toxicity in the marine environment resulting from leisure boat antifouling paint consumption. These concern;

- i) *Reduce copper concentrations in antifouling paints and an ultimate goal of phasing out biocidal antifouling products used on leisure boats in the Baltic Sea.* Based on repeated field tests, we can conclude that a paint with low copper content (4,3 % copper oxide) has 100 % antifouling performance during a full boating season in the Baltic Sea. Furthermore, there is ample scientific evidence from studies performed within BONUS CHANGE that excessive amounts of copper are present in current commercial antifouling paints. Not only are the copper release rates unnecessarily high for some products (i.e. more copper is released than what is needed for fouling protection) but the specified lifetime of the products is generally not representative, leading to unnecessary high frequencies of re-painting. The latter leads to build-up of copper on boat hulls, and ultimately, pollution of boatyard grounds. During the transition-phase to reach the goal of a Baltic Sea free from biocide-based antifouling paints, we recommend using the minimum amount of copper in the antifouling paint that reflects the service life

of the paint and with a release rate of copper that ensures antifouling efficacy for that service life. Findings also show that biocide-free silicone paints have the same antifouling performance as high copper content paints in repeated boat tests. Moreover, our evaluation of biocide-free antifouling techniques shows excellent performance in preventing marine biofouling in the Baltic Sea and should be promoted.

- ii) *Improving antifouling practices and maintenance work in marinas through regulations and infrastructure to reduce spread of antifouling toxins to the ground and to the sea.* This can include infrastructure of clearly depicted boat wash sites with water treatment facilities, mandatory use of tarps for trapping old paint scrapings and fresh paint drops in marinas. It could also imply containers specifically intended for paint residues collection in marinas. Moreover, proper infrastructure could also contribute to limit the spread of old TBT paint layers that still are present on many leisure boats. Adaption of existing, or developing new, eco-labelling scheme for marinas that targets antifouling could further encourage this development.
- iii) *Urging governance, policy and regulatory measures* that include applying the regulations of the Biocidal Product Regulation (BPR) in a way that support restrictive national implementation in order to limit the use of biocidal antifouling paints. The assessment of regulatory options concludes that there is room for restrictive interpretation of the BPR, like the one in Sweden, for all Member States in the Baltic Sea. The sensitivity of the Baltic Sea can for example be used for such restriction. Furthermore, striving to make the Baltic Sea free from antifouling biocides could also be promoted within the HELCOM, in reference to the goal on hazardous substances in the Baltic Sea Action Plan. Moreover, substantial shortcomings of the current standardized release rate methods have been revealed through the determination of field release rates of copper from antifouling paints, using a new quantitative XRF method. This must be considered in future risk assessment and authorization.

These statements are based on BONUS CHANGE's policy recommendations which are thoroughly described in the publication *BONUS CHANGE Recommendations Towards Regulations for Sustainable Antifouling Practice in the Baltic Sea* (ISBN: 978-91-87869-13-6).







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